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REPORTER'S DISCUSSION OF TOPIC 7(a)

"Wind Erosion, Dunes, etc."

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for the Round-table Discussion on

The Role of Hydraulic Laboratories in Geophysical Research

at the

National Bureau of Standards

on September 13, 1939

Introduction

In recent years the movement of soil material by wind has accelerated to such an extent that it has become a national problem. In the United States, the Great Plains is the largest and most seriously affected area, although soil drifting is by no means confined to this region. It is a grave problem in other agricultural sections; local areas in the northwest, California, Iowa, and numerous other states are subject to soil movement. Similar conditions exist throughout the world, notably in Canada, Australia, and Palestine.

In the broader sense, wind erosion is the removal of soil or soil material by wind from one location and its deposition in another. All degrees of the process can be found in the Great Plains, from areas with only slight movement to those in which dunes thirty feet in height have developed, and corresponding eroded areas where several feet of soil have been removed. Dust and sand storms are other expressions of wind erosion by means of which the finer soil particles are carried and deposited often many miles from the starting point.

The development of measures for the control of wind erosion is dependent on a basic knowledge of the causes involved. Variables which need to be considered in the study of wind erosion are:

1. Soil: texture, structure, moisture content, organic content.
2. Organic Soil Binders: roots, imbedded surface litter.
3. Topography: undulating, flat, rough, etc.
4. Obstructions: vegetation, loose surface litter, hummocks, engineering structures such as terraces, furrows, ridges.
5. Climatic conditions:
  - a. Wind Characteristics - velocity, direction of flow, character of flow (turbulent, streamlined).
  - b. Climatic Characteristics - humidity, temperature, barometric pressure.

\*Material supplied by Mr. Frank J. Malina, Dr. H. T. V. Smith and others has been freely drawn upon.

EROSION-EROSION CONTROL



Study and analysis of the influence of the above variables on the degree and extent of wind erosion should lead to an understanding of the basic causes of this process. Although field experiments are of primary importance, there is little question that controlled experimental studies on a smaller scale would be of great practical value.

### Wind Erosion Investigations

Wind tunnel researches on soil drifting are being carried on at the Soil Research Laboratory, Swift Current, Saskatchewan. Two tunnels are being used. One is a small laboratory tunnel 6 feet long with a cross section 2 x 2-1/2 feet, powered by a variable speed motor capable of delivering winds up to 35 m.p.h. The other, known as a portable tunnel, is 28 feet long, 4 feet wide, 3-1/2 feet high, with no top. Powered by a gasoline engine, this latter apparatus is capable of delivering winds up to 35 m.p.h. The tunnel can be disassembled, loaded on trucks and carried to the field where studies can be made.

Some of the results obtained to date are as follows:

1. The structure of the wind and the nature of the movement of soil in the field and in the portable tunnel were found to be similar, but the small laboratory tunnel did not duplicate outside conditions too closely. However, the relative effect of various cultural treatments on the susceptibility of soil to drifting showed general trends similar to those in the field.
2. The relative effects of some cultural treatments on soil drifting as determined in the laboratory tunnel were as follows:
  - a. Effect on wind velocity, one foot above the soil, required to initiate soil movement:

|                              |           |
|------------------------------|-----------|
| (1) Smooth bare surface      | 15 m.p.h. |
| (2) Ridged surface           | 17 m.p.h. |
| (3) Surface mixed with straw | 20 m.p.h. |
  - b. Effect on amount of soil blown away:

|                              |                              |
|------------------------------|------------------------------|
| (1) Smooth bare surface      | 133 grams in 5-minute period |
| (2) Ridged surface           | 55 grams in 5-minute period  |
| (3) Surface mixed with straw | 14 grams in 5-minute period  |

The tendency of soils of various textures and various structures to blow at various wind velocities was determined. The nature of the movement of soil material was studied in the portable tunnel and found to agree with the results obtained in the field. The vertical velocity gradient was found to depend on the nature and size of the irregularities of the surface in the manner given by Prandtl's formula. This result was obtained both in the open field and in the portable tunnel.

In surveying their results, of which the above is but a partial account, Chopil and Milne of the Swift Current Laboratory conclude that "a wind tunnel of sufficient size can be accepted as a means of practically duplicating field conditions".



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In the attempt to combat wind erosion many investigations have been conducted in the field to determine the destructiveness of various farming methods and the effectiveness of various corrective measures. Some conclusions are as follows:

1. The most effective means for controlling wind erosion is an adequate cover crop.
2. Moisture conservation methods such as terracing and contour furrowing aid in securing a cover crop and thus decrease the erosion hazard.
3. Close drilled cover crops are more effective than wide rows in controlling sandy soils.
4. A rough cloddy surface aids materially in controlling soil drifting.
5. Various tillage operations such as deep listing are helpful in controlling wind erosion.

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J. S. Atsumi studied shelterbelts in a wind tunnel at the California Institute of Technology. The purpose of the experiment was to determine the arrangement of trees giving the maximum protection per tree and per shelterbelt. Since the scale of the experiment was very small, the model trees being only 1 inch in height, the quantitative results cannot be expected to carry over



into full-scale conditions. However, the tests make possible comparative studies of tree planting arrangements and the relative effectiveness of a shelterbelt.

The results of the tests show that a single row of trees planted with space between adjacent trees equal to the height of the trees gives the greatest windshielding effectiveness per tree, that a double row of trees with space between the rows and also between adjacent trees equal to the height of the trees gives the greatest windshielding effectiveness per shelterbelt, and that the minimum distance required between two shelterbelts is approximately 8 to 10 times the height of the trees when the wind direction is perpendicular to the shelterbelts.

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Wind tunnel researches on the movement of desert sand by wind have been carried on by R. A. Bagnold, at the City and Guilds College, London. The apparatus used was a 30-foot long sand tunnel, 1-foot square. It was powered by a suction fan capable of producing winds up to about 25 m.p.h. Sections of the tunnel were supported separately on spring balances to record the net removal of sand while the experiment progressed. Some of the results obtained by Bagnold follow:

1. The determination of a threshold wind - i.e., the wind velocity which barely maintains a steady drift of sand, and of a static threshold wind - i.e., the velocity required to initiate surface drift.
2. The static threshold wind depends on the history and the size of the exposed surface, the turbulence of wind, and size of the sand grains.



3. A study of sand deposition leads to a theory of the formation of sand dunes. According to Bagnold's results, a dune would grow if there were a sandy patch in the midst of a large pebbled area, and if there were a gentle wind supplying sand from some distant source to the pebbled area with occasional gusts to heap this sand onto the sand patch.
4. At least three ways for sand particles to be deposited were studied:
  - a. Accretion occurs when height-velocity gradient diminishes over a flat surface; particles merely drop out and transport by creep falls off.
  - b. Encroachment occurs in the lee slope of dune or residue ridge; creeping particles roll over the top and fall into protected area and accumulate.
  - c. Sedimentation occurs where the wind falls below the threshold value.

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Sand dune areas have developed near Dalhart, Texas in recent years as a result of wind action, improper land usage, and adverse climatic conditions. From field studies devised by Charles J. Whitfield for the stabilization of this sand dune area, the following observations were made:

1. Sand is transported by wind velocities of 9 m.p.h. and above.
2. Sand dunes above 12 - 18 feet in height move very little, if at all. They tend to maintain themselves, apparently, through the development of a back pressure on the leeward side of the dune.
3. Dunes under 12 feet in height have a tendency to be constantly shifting, often completely disappearing in one season. On one 470-acre field, 57 dunes up to 12 feet in height were entirely disseminated.
4. Dune areas increase in size by the formation of new dunes rather than by movement of large dunes.
5. Studies of dune formation aided materially in the development of control methods.
6. Practical and economical methods for the control of sand dune areas in this region were developed by using wind action to redistribute the sand that had built up into dunes.

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#### Work Now In Progress

Much of the work mentioned above is being continued. Some problems for which studies are being planned and initiated are as follows:

1. The effect of different methods of tilling the soil on its tendency to blow.
2. Types of vegetative cover best suited for holding the soil.
3. The design of obstructions such as terraces, ridges, etc.
4. The effect of texture, structure, moisture, humus content, etc., on the resistance of soil to blowing.
5. Methods of reclamation and control of sand dune areas.
6. The efficiency of wind-breaks in preventing soil blowing and diminishing the evaporation of moisture from soil.
7. The mechanism of the lifting of the soil from the ground and the the mechanism of the transportation and of the deposition of blown particles.
8. The dependence of the amount of soil blown on the velocity of the wind, its structure, and its physical characteristics.
9. The effect of the soil surface on the velocity distribution of the wind near the ground.
10. The size distribution of particles transported at different wind velocities.

At the Amarillo Experiment Station, 14 miles west of Amarillo, Texas, a research work area maintained on a 1600-acre farm by the Soil Conservation Service, a complete soils laboratory has been established. Studies have been initiated to determine, in the laboratory, the effect of texture, structure, moisture, humus content, etc., on the resistance of soil to blowing. Soil samples will be collected from critical areas throughout the Central and Southern Great Plains as these investigations are being carried on in close cooperation with State Experiment Stations as well as with Soil Conservation Service Research men now available in the various states. Supplemental research will be carried out on the station. The relation of various tillage and agronomic practices to wind erosion are being studied under controlled conditions in an attempt to develop a farming system for this region.

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At the Dalhart sand dune research area, investigations dealing with the control and stabilization of sand dune areas have been under way since 1936. With funds now available, studies are being contemplated for analyzing sand transportation and dune formation with a view of formulating the fundamental principles governing these processes. It is believed that such an analysis will be of service both to the science of agronomy and to the science of geology. To agronomic science a genetic understanding of dune development will bring a more direct approach to problems of dune control, reducing the time and expense incident to study of particular problems in new areas where environmental conditions are either slightly or considerably dissimilar to those of experimental tracts. To geologic science, these studies should contribute a better background for tracing the history and discovering the geomorphic and climatic significance of existing dune fields, and for interpreting ancient dune sands now incorporated in the sedimentary column.

Studies to be undertaken or continued where already begun are as follows:

1. Tabular summary of available meteorological data, including mean and extreme monthly precipitation, prevailing wind direction and average wind velocity for each month; and for each month for 5-mile intervals per hour the number of hours during which winds blow from each of the eight compass directions.
2. Geomorphic forms of dunes.
3. Stratification of dunes.
4. Comparative wind velocities at different heights and in relation to different dune positions.
5. Flow lines of air currents over and around the different types of dunes at different wind velocities.
6. Source of sand supply.
7. Transportation of sand.
8. Accumulation of sand.
9. Growth and migration of dunes.

At the California Institute of Technology, Pasadena, California, Frank J. Malina, Cooperative Agent, Soil Conservation Service, has developed plans under the supervision of Dr. Theodore von Kármán, for the construction of suitable apparatus which can be used to study many of the problems enumerated above. The apparatus in which the experiments are to be made is a soil-blowing tunnel and is of two types.

The semi-permanent tunnel is an apparatus in which complete control can be had of the various factors connected in the soil blowing. It is semi-permanent in that the equipment can be shipped from one section of the country to another. The portable tunnel is a wind machine designed in such a way that it can be used in the field. The component parts of the apparatus can be dismantled in a short time and transported on an automobile-drawn trailer.

The apparatus for the semi-permanent tunnel consists of three basic components: a wind-making machine, soil blowing channels, and the observation equipment. In order to increase the operating efficiency, several channels are proposed so that while tests are conducted in one channel, those idle can be prepared for testing.



The wind machine consists of a power unit capable of delivering a maximum 400 h.p., two 12-foot propellers driven by chain drive, and a wind stream collector with honeycomb for directing and smoothing the wind stream. A wind velocity ranging from 5 to 60 m.p.h. of the type flow structure desired can be directed on the prepared plot in the channel. At the maximum speed of 60 m.p.h., air passes through the collector outlet at the rate of 1,056,000 cubic feet per minute.

The wind machine is set up on a platform resting on four trucks riding on two standard gage railroad tracks. This arrangement makes possible the transfer of the wind machine from one channel to another.

Each soil blowing channel is 80 feet long, 25 feet wide, and 8 feet high. These dimensions reduce wall interference and permit close approximation to field conditions.

A movable structure bridging the channel is provided from which observation of the soil blowing process can be made. It can be moved on rollers to any location over the channel and provision has been made to transport it on the wind machine carriage from one channel to another.

The soil blown down the channels will give no difficulty if the apparatus is installed on a large plot of ground away from inhabited districts. Various methods of trapping the blown soil were considered. It was found that any method available was prohibitively expensive. Model experiments are planned to devise a simple scheme for reducing the distance within which the blown soil settles.

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#### Future Status of Wind Erosion Investigations

Very little basic work has been done in the United States on the important problem of wind erosion. Although plans have been developed and some work started, with the present facilities and funds available, progress is slow.

It is neither economical nor desirable to attempt a trial of all possible systems of farm management on each soil type for the various agricultural sections. It is here that preliminary laboratory investigations could play an important role, for on the basis of experiments under controlled conditions, the most likely systems for trial may be determined.

There are many problems which can be attacked more quickly and with more certainty in the results if first subjected to controlled tests in the laboratory. That such investigations are justifiable has been shown by the work at Swift Current, Saskatchewan, and Bagnold's studies at the City and Guilds College, London. It is therefore felt that considerable benefit could be derived by laboratory study of the wind erosion problem.



*Flood control file*

EXCEPTIONS TO KICKAPOO RIVER SURVEY REPORT

by Raphael Zon  
Chairman of Field Coordinating Committee

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Feeling that the Kickapoo Survey Report at this stage is of a decidedly tentative nature, due to incompleteness of certain investigations, the Chairman of the Field Committee would have preferred, at various points, particularly in Section IV, and in the Syllabus and Summary, a form of statement which leaves the final decision plainly open, particularly as to the choice between giving primary emphasis to the land-use program, and giving priority to the most complete system of detention reservoirs, that accurate surveys might show to be justified.

First, it is necessary that the detention reservoirs claim first benefits of flood reduction if they are to be justified to any important extent, rather than being superimposed on the land-use program, assumed to have brought about certain primary benefits. In short, in view of the uncertain effects of the land-use program, and the very positive effects which can be guaranteed by reservoirs, whenever and to whatever extent constructed, we can see no reason for giving any priority to the land-use program, as a flood control measure. Admitting that it is desirable to accomplish the objectives of better land use and of flood control at the same time, it is still necessary, in the interests of flood control, that we support that program which will give certain flood protection, and the most protection that is possible. This point of view is the more tenable because practically all benefits of the land-use program can be had without approaching it as a flood control program, and our data indicate that other benefits would justify it in its entirety.







Secondly, without minimizing in the least the need for land-use changes, nor the importance of the soil conservation objective which is the primary basis of such changes as are now, and will continue to be effected under programs enjoying the guidance of the Soil Conservation Service, we are compelled to view with pessimism, as a practical measure, the possibility of substantial flood reductions as a result of these programs. There are two distinct reasons for such doubt:

a. The human element. The runoff reduction phases of a land-use program, except as runoff results directly in loss of valuable field soils, do not interest the farmer. This phase is not his program. His program is to save his investment in the soil, and to practice a more profitable form of agriculture if possible. Add to this inevitable apathy toward runoff reduction as such, the immensity of the task of inducing 3300 farmers to follow any enlightened program, and to keep them interested and "in line" through a long period of years, and it is evident that, even with a substantially growing interest in soil conservation, the possibility of accomplishing 50 percent of the theoretical flood reduction benefits is remote indeed.

b. Under what may be termed a "technical doubt" must be mentioned the hiatus which seems to exist between runoff differences for small plots--carefully handled to emphasize the effect of different cover and cultural conditions--and what is obtained from these same forms of land use are employed on a large scale under practical farming conditions. Merely as an example, the favorable runoff characteristics of a plot of hay may be largely lost if, under practical conditions, the hay land is grazed and trampled, or even if it becomes compacted only through the use of heavy machinery. Likewise, little or nothing is known as to the effects of different degrees of grazing on soil compaction, as a factor in runoff separate and distinct from the effects of cover density. These examples may be multiplied indefinitely.







Equally important, however, is the variability of infiltration rates from time to time, and the many questions as to their application to any specific storm conditions.

These matters, when taken in conjunction with the apparent lack of tangible flood reductions in the case of the Coon Valley Demonstration Project, lead to the conclusion that, even with the exercise of great conservatism, it is easily possible to overestimate the effects of land-use changes--as they will be applied in practice--upon runoff and runoff reductions. Even though it were felt that the sample-plot data, and the infiltration tests, to which this Survey has referred, were exhaustive and beyond question, it would still be necessary, in view of practical considerations, and the watershed evidence as far as it goes, to entertain a doubt as to whether theoretical benefits are possible of attainment.

In referring above to the records of the Coon Valley Project for the first five years after initiation thereof, we mean only to imply that by our analysis the results are negative. Were the program as effective upon runoff as theoretical considerations dictate, there should be a measurable change in flood volumes, which apparently has not occurred. More exhaustive analysis may indicate an infinitesimal change which is statistically significant. It would seem to be important to go into this exhaustively, and we shall gladly admit our error when it is proven.

In view of the exceptions now taken, it would seem that the report goes into undue elaboration of the land-use program as a flood control measure. The reason for this is that the Committee had an honest desire to make land use the pivot of the program, and thought at the outset that little else would be necessary. It has only been after a long struggle, and repeated analysis of all of the factors involved, that the Station has reluctantly concluded that changes in land use, in a section supporting a large agricultural population, cannot give a satisfactory solution of the flood problem.







HOUSE OF REPRESENTATIVES, UNITED STATES  
COMMITTEE ON AGRICULTURE

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A REPORT

ON

“THE INFLUENCE OF FORESTS ON CLIMATE  
AND ON FLOODS”

BY

WILLIS L. MOORE, LL. D., Sc. D

*Chief of the U. S. Weather Bureau*

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NOTE.—When Professor Willis L. Moore was before the Committee on Agriculture of the House of Representatives in 1909, to explain the estimates for the Weather Bureau, a discussion arose as to the influence of forests on climate and on the run-off of water. Professor Moore stated that he was then making some studies on the subject which might lead to some definite conclusions, and he was requested by the chairman of the committee to continue these studies and make a report when they were concluded. This has been done, and the report submitted by Professor Moore, which follows, is printed by direction of the committee.

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WASHINGTON

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# THE INFLUENCE OF FORESTS ON CLIMATE AND ON FLOODS.

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By WILLIS L. MOORE, LL. D., Sc. D., *Chief U. S. Weather Bureau.*

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## INTRODUCTION.

One of the most important problems before the American people to-day is the protection of their natural resources against either the greed of those who would monopolize them for their own individual benefit or those who, while well meaning, would through ignorance destroy our heritage and leave posterity poor.

In the discussion of matters concerned with the conservation of the natural resources of the nation, some of which may involve the expenditure of hundreds of millions of dollars and the employment for years to come of thousands of public officials, a consideration of the relation of forests to climate, floods, and low water is vitally important.

While much has been written on this subject, but little of it has emanated from meteorologists or from those in the public service who have been actively engaged in the forecasting of river stages, both of high and of low water. In the prosecution of such duty these officials have become acquainted with the physical facts involved in the problem and are therefore well fitted to speak on the relation of such facts to stream flow.

## THE AUTHOR ACKNOWLEDGES A CHANGE OF OPINION.

It has frequently been stated that forests control the flow of streams, both in high-water stages and in low-water stages, and that the climate is so materially affected by the cutting away of the forests that droughts have largely increased and that the well-being of future generations is seriously menaced. It is my purpose to present facts and figures that do not support these views, some of which, especially those that pertain to the flow of streams, were held by me up to a few years ago—until a careful study of our own and other records and of the incidents of history caused me to modify my opinions. I shall endeavor not to be dogmatic, but rather to present the reasons for the conclusions that I now entertain, with, so far as may be, statistical and historical evidence to sustain them. And I reserve the right to change or still further modify my views if the presentation of new facts and figures render such a course logical, and do not consider that I shall stultify myself in so doing.



## FORESTS SHOULD BE PROTECTED.

There are so many reasons why forests should be protected by the state and the nation and economically conserved in the interests of the whole people that it is doing an injury to a good cause to attempt to bring to its support the false reasoning and mistaken conclusions of enthusiasts, no matter how well meaning they may be or how devoted to high and lofty purposes.

Conservation of national resources is national economy, just as conservation of private resources is personal economy. But whether personal economy is beneficial or harmful to the individual and his children depends upon the extent and nature of that economy; and the same thing is equally true of a nation. Conservation that prevents the practical use of individual or national resources is like unto the economy of the timid servant that hid his master's talent in the earth, and in large measure deserves the same condemnation.

There should be neither wasteful use of resources nor that greatest waste of all, total disuse of them, but that economical use which in the end will have yielded the greatest good to the greatest number.

Preservation of the forests, cutting wisely, but never more than they reproduce, enables us to draw from a perpetual supply a certain quantity of material for buildings, for furniture, and for fuel. But of course the *forested land yields not a handful of wheat nor of corn and makes but a wretched substitute for the pasture upon which to feed milch cows and beef cattle.* These conflicting interests, the pleading of the poor man's children for bread and meat and the cry of the country for the lumber that only a woodland can furnish would, if there were no other interests to modify the result, somewhere find an inevitable balance. But just as the body is more important than its raiment, so, too, is its food more important than its shelter; and therefore in every country *the general tendency, with growth of population, is to convert forest lands into cultivated fields, and this tendency should not be discouraged unless it can be shown that deforestation has augmented droughts and floods, and I believe that it can not be so shown; I believe that forests should be preserved for themselves alone, or not at all.*

The average virgin forest is wasteful as a source of lumber and of fuel. It is only here and there that a tree is found of proper growth and suitable species for first-class material. As a lumber producer a forest of this kind is analogous to a cornfield planted in scattering hills here and yonder, instead of being cultivated throughout its extent and planted with that regularity and closeness of spacing that will produce the maximum yield. If the expense is not found to be too great in comparison with the return, forests should be cultivated with the same care both as to species and as to distribution, and possibly, too, as to rotation, that the intelligent farmer uses in planting his fields. In this way returns equal to what we now get could be secured from a much smaller forested area, and *there can be no valid objection to decreasing the area where homes and a well-fed people take the place of wild animals and the wilderness.*

It is found that in some limited areas where the forest is cleared away, the soil, owing to its nature and slope, will not admit of successful cultivation. It may wash so badly under heavy rains as to become unfit even for reforestation. In others, owing to the nature



of the surface, cultivation is impossible. These are fit places for local control, provided such control is commercially feasible, but not for national control, *unless it can be demonstrated that the conditions at these places materially affect the navigability of streams or harmfully affect the climate of the continent at large.*

The great value of forests as fuel producers is admitted on every hand, and because of the growing cost of coal their importance in this particular is likely to increase rather than diminish, and of course without them the world would be deprived of that beautiful building material which from the earliest ages it has used so freely and regarded as indispensable, but which in the future may be used in a less ratio as the use of noncombustible materials, like concrete, stone, and steel, becomes more general, and certainly their use will increase. No reason in addition to these can be needed to justify an immediate and vigorous effort on the part of individuals, and especially on the part of governments, to teach and to insure the wisest national use—that is, wisest use when both the present and the future are properly considered—of all existing forests, and also where and how best to secure other forested areas.

Nevertheless additional reasons are urged, and in some cases urged as the paramount reasons for forest conservation, which will not stand the test of investigation.

#### EFFECT OF FOREST ON CLIMATE.

It is often said that the climate of a given place depends upon the extent and proximity of wooded areas; that the number of rainy days and the total amount of rainfall are modified by change of forest extent; that the depth of floods, the shallowness of low water, and the regularity of flow are all profoundly modified by changing the proportion of fields to forests in the watershed.

Now, the extent and even the nature of these influences is not a matter, as often is implied, of universal agreement. In regard to change of climate, regardless of the cause, trustworthy records of temperature, of rainfall, and of other meteorological elements do not cover a sufficient range of time to furnish all the data necessary for a *statistical* solution of this problem. However, there appears to be plenty of evidence that there have been times in the remote past when the salt seas both of Asia and of America had surfaces of greatly increased size over those that now exist. There is evidence also that in certain of these regions trees once grew more abundantly than is now the case. This, however, must not be taken as proof that there has been a decrease of rainfall due to destruction of the forests. It is true that the forests have diminished—in some cases wholly vanished—and it is also true that the evidence strongly supports the assumption of a decrease in rainfall, and therefore, of course, of a greater or less change of climate; but this decrease of precipitation might better be regarded as the cause rather than as the result of the barren condition of the soil. There is no evidence that the forests were ever more extensive in Alaska and in other high-latitude countries than they now are. Nevertheless, in these countries, too, just as in arid regions of the great continents, there is evidence of the same slow, long-period climatic change—a decrease of precipitation or an increase of temperature, or both—a change that can



not be due to deforestation. This evidence consists in the slow irregular retreat (followed once in a while by a slight advance) and diminution of the glaciers, which phenomenon is said to be universal regardless of latitude, of longitude, and of elevation, and which appears to have been in more or less steady progress with, however, occasional temporary relapses of one or another magnitude since the culmination of the great ice age. In fact, we can reasonably say that we are even yet in the ice age—a vanishing age to be sure, but one not wholly gone—and, further, that whatever marked climatic changes take place they are essentially universal and not local.

Prof. William J. Humphreys, Ph. D., Johns Hopkins, professor of meteorological physics, United States Weather Bureau, says:

These universal slow climatic changes that for thousands of years have been modifying the glaciers and changing the inland seas might very well have led to extensive forest destruction; but that it itself was the effect and the destruction of the trees the cause seems most unlikely.

#### DESICCATION IN ASIA.

In this connection I would refer to the opinion of Mr. Ellsworth Huntington, B. A. of Beloit and M. A. of Harvard. For four years, 1897–1901, he was the President's assistant and instructor at Euphrates College, Harput, Turkey. He explored the canyon of the Euphrates River in 1901 and was awarded the Gill Memorial by the Royal Geographic Society of London. He was research assistant in the Carnegie Institution, of Washington, and was a member of the Pampelly expedition to Russian Turkestan in 1903–4. He spent one and one-half years in Turkestan and Persia and a like period in India, China, and Siberia as a member of the Barrett expedition. He has been instructor in geography at Yale since 1907. He explored the Lop basin in Chinese Turkestan, whose length is 1,400 miles and whose maximum width from north to south is 400 miles, embracing an area as large as that portion of the United States east of Lake Michigan and north of Tennessee. Most of the basin is desert. In an article in the Monthly Weather Review for November, 1908, dated at Yale University, November 10 of the same year, he says:

The Lop basin contains abundant evidences of climatic changes, and has been discussed in detail by the writer in "The Pulse of Asia." Throughout the basin the amount of vegetation has greatly decreased in recent times without the intervention of man. On the lower slopes of the Kuenlun Mountains the dissected condition of numerous deposits of loess shows that a cover of grass prevailed at no remote date, but has now disappeared. In the zone of vegetation plants of all kinds show signs of a process of drying up which has been in progress for centuries. Tamarisk bushes stand upon mounds from 5 to 60 feet high, a sure sign of the lowering of the level of ground water; poplar forests which once extended for scores of miles now form wastes of branchless dead trunks like gaunt gray skeletons; and beds of dead reeds cover hundreds of square miles. It has often been asserted that the destruction of forests has been the cause of the diminution of rainfall. In the Lop basin the opposite appears to be the case; the supply of water has diminished, and therefore the forests have died. Rainfall unquestionably controls forestation, but neither in the Lop basin nor in other parts of central and western Asia is there any good evidence that forests have an appreciable effect upon rainfall.

Another important line of evidence is found in the relation of rivers to the desert of Taklamakan and to ruins of ancient dwellings. On the south side of the Lop basin, from Khotan eastward to Lop Nor, the writer examined seventeen streams which are worthy of notice, because of their size or because they support oases. All but four come to an end in the zone of vegetation, where they spread out and disappear either naturally or because used for irrigation. Hence it is impossible to determine whether



or not they have decreased in length. At the lower ends of the other four, old channels are found lined with dead forests, which prove that the streams once extended from 8 to 25 miles farther than is now the case before finally becoming swallowed up in the sand.

#### FORESTS IN EVIDENCE AFTER STREAMS HAVE DRIED UP.

*The fact that dead forests stand long after the streams have receded seems to prove that they are the last to disappear rather than the first, and therefore that their removal did not precede the drought but rather that the forests ceased to exist when the rainfall became deficient. Unmistakable evidence is found of the existence of extensive forests in Arizona and New Mexico, where only the petrified trunks of trees now remain. It can not be said that man removed these forests and brought on the drought.*

#### LOCAL CLIMATIC INFLUENCES OF FORESTS.

One may conclude from the evidence gathered from many sources that summer temperature is slightly less in the forests and in their neighborhood, especially to the leeward, than it is in corresponding cleared sections. Forest temperature is also slightly higher during cold weather than is that of open fields, due presumably to the interference of the trees, even when of the deciduous type, with free ground radiation.

The increase of winter temperature, however, is not equal to the decrease of that of summer, the season during which most vegetation needs all of the heat it can get; and, therefore, it happens that wooded areas may slightly retard the growth of crops in their neighborhood, as is said to be the case in the uplands of Mauritius.

With regard to the effects of forests on rainfall, I quote the following from recent writings of Prof. Cleveland Abbe, who is the senior professor of the Weather Bureau and a member of the National Academy of Science. He says:

It is a pity that the errors of past centuries should still continue to be disseminated long after scientific research has overthrown them. It is easy to start false theories and to believe them, because they are generally simple and plausible, but long years of work are necessary before we get at the secrets of nature. In this day and generation, the idea that forests either increase or diminish the quantity of rain that falls from the clouds is not worthy to be entertained by rational, intelligent men.

Gauges exposed over forests universally catch more than gauges exposed at the same elevation in the open. Professor Abbe explains this as follows:

The main trouble consists in the assumption that the water caught and measured in the rain gauge correctly represents the rainfall. Perhaps the most interesting observations bearing directly on this question are those made by Brandis and Blanford in India, where rain gauges were placed both on the ground and above the tree tops at the height of 60 feet in well-watered regions. The high gauges in the forest recorded 4 per cent greater catch than those at the same height in the open fields, and the low gauges on the ground in cleared spaces in the forest gave 2 per cent greater catch than those in open lands. But these figures do not prove that the forest received more rain than the clear areas, although at first sight they would seem to confirm that idea. The fact is that the forest gauges were better sheltered from the wind than the open-ground gauges and this caused them to catch a larger proportion of the rain that fell.

The rain gauge has several sources of error that must be investigated and allowed for, as in all other meteorological apparatus, so that we may not use crude and imperfect data. The effect of the wind in diminishing the catch of the rain gauge has frequently been investigated since the first studies by Mickle in 1819, and the present state of our



knowledge was convincingly summarized \* \* \* in 1887 in an Appendix to Bulletin 7, published by the Forestry Division, United States Department of Agriculture. This Bulletin, edited by B. E. Fernow, "the father of American forestry," recounts the various methods appropriate to the determination of the true amount of precipitation, and its bearing on theories of forest influences.

It appears that in ordinary rainfalls we have a mixture of large and small drops of water descending with various velocities that depend on their size, density, and the resistance of the air. Particles of hail descend even faster than drops of water, but flakes of snow fall more slowly. When the wind strikes the side of a rain gauge the deflected currents move past this obstacle more rapidly, and there is an invisible layer of wind above the open mouth of the gauge, whose horizontal motion is more rapid than that of the wind higher up. Some of the larger falling drops may descend with a rapidity sufficient to penetrate this swiftly moving layer of air, but the slower ones will be carried over to leeward and many will miss the gauge. The resulting loss of rain will depend upon both the horizontal velocity of the wind and the vertical velocity of descent of the rain.

The fact that the deficit increases with the velocity of the wind (which is less over the forest) has also been proven in a different way, viz, by shielding the gauge from the wind, when the deficit becomes greatly reduced in value. Professors Henry, Nipher, Boernstein, Hellmann, all of them eminent investigators, agree in this conclusion.

Of two gauges exposed at the same elevation above the ground, one over the open fields and the other over a forest, just above the tops of the trees, the one over the forest will catch considerably more rain, because the friction of the trees reduces the velocity of the wind and it does not rush across the open end of the gauge with the same speed that it does across the gauge over the open fields.

The influence of a forest upon the rainfall is therefore only apparent; it may increase or diminish the *catch of the gauge*, but not the quantity of *rain falling from the cloud*.

Professor Abbe further says:

If gauges are raised up year by year, the deficit increases; if gauges in open fields become surrounded by growing trees or higher buildings, the deficit decreases. The *climate* has not changed, but the *errors of the record* have done so. Those who wish to restore the good old times before the forests were cut down, when rain and snow came plentifully and regularly, have only to lower and shelter their rain gauges and snow gauges and, *presto*, the climate has changed to correspond.

When rain is falling on a forested region, about 25 per cent is temporarily held far above the ground on the leaves and branches of the trees. In this minutely divided condition, exposed to the action of the wind, the drops evaporate freely, so that the forest atmosphere becomes saturated and decidedly less moisture reaches the ground to be absorbed in the forest humus than on an equal volume of soil outside the forest. A special climate is therefore maintained within a forested area. The temperature is lowered and the relative humidity is increased, but there is no evidence that this local forest climate extends outside the forest or affects exterior conditions to any important extent. Of course, the climate under a tree or a tent or within a house differs from that outside, but these are local matters quite foreign to the broad question, Do forests affect climate?

The climate within a house is not the climate of the whole city, nor is the climate of a ravine that of the surrounding fields. One thermometer or rain gauge in the open air does not give the climate of a State or watershed. The various and restricted uses of the word "climate" have led to our confusion.

#### LOCAL TEMPERATURE DIFFERENCES DUE TO CHARACTER OF SOIL COVERING.

As the result of investigations begun in Wisconsin by the author over fifteen years ago and continued during the past three or four years by Prof. Henry J. Cox, of the Weather Bureau, we have found that surprising results are obtained on two surfaces of precisely the same level on adjacent fields, one of them covered with thick vegetation and the other covered 2 inches deep with sand. We have



noted differences in temperature frequently of  $7^{\circ}$  to  $9^{\circ}$  in the air immediately adjacent to the surface or within a stratum 3 inches deep, this difference being so great that one area would receive a heavy deposit of frost and the other (sanded section) be entirely free from such frigid temperatures; and the difference in temperature between a thermometer exposed in the heart of a city and one in the open field but a few miles away was found to be marked. As an illustration: A thermometer in a shelter at La Crosse, Wis., registered  $50^{\circ}$  minimum temperature on a certain morning, while a thermometer in the cranberry marshes 50 miles away fell to freezing; but these were all local irregularities. The difference in temperature between the air over thick vegetation and that over the sanded surface disappeared within a height of 3 feet, and it is probable that the temperature over La Crosse and over the cranberry marshes was the same at an altitude of 200 feet.

#### CHANGING THE LOCAL CLIMATE BY ARTIFICIAL CONDITIONS.

The covering of tobacco plants with thin cheese cloth results in establishing a local climate which will continue so long as the cheese cloth remains in position. The extremes of temperature, both heat and cold, are reduced, and the resulting climatic change produces a marked effect upon all vegetation grown under the artificial conditions. The erection of a tent, of a barn, of a dwelling house, of a village, or the growth of a great city, respectively, influence the local climate in proportion to the area that is covered, modified by the character of the material used in these constructions. Likewise the vegetable covering of the earth may have a local appreciable effect. The flooding of an area, the cutting away of forests, erosion, and sanding may have either minute or appreciable effects upon local climates in proportion to the magnitude of the areas affected, *but this does not mean that there is any great difference in the climatic effect between a forest covering and one of bushes, of grass, or of growing crops; and it does not signify that there is sufficient change in the thermal conditions, due to the activities of man, as to make an appreciable difference in the temperature at an altitude of one or two hundred feet, or to affect the general climatic conditions, or to cause storms to be more frequent than formerly or of greater severity, or to increase the amount of precipitation.*

#### A PLEA FOR TOLERANCE OF OPINION.

But this discussion should not be approached in an intolerant spirit. We have accurate records of climate from only a few isolated places in this country that extend back for a period of as much as one hundred years, and the Government's extensive records only cover a period of forty years. I would warn against hasty conclusions; against accepting as final the deductions of several investigators who have recently publicly discussed the flood records of the Weather Bureau. They find a most alarming increase in the floods of the Ohio Valley and other places, for which I find no justification. Let logic, reason, and investigation have time to operate, for any man may be honestly mistaken and draw general conclusions from inconsequential details or deceive himself by the improper grouping of data.



## RECORDS OF PRECIPITATION SHOW NO MATERIAL CHANGE.

The records of precipitation of the United States Weather Bureau do not show that there has been any appreciable permanent decrease in the rainfall of any section of the United States. There are undoubtedly periods covering a number of years of continued deficiency in precipitation for certain districts, but at the same time other districts may show a corresponding increase. One of the best and longest records of precipitation of the eastern part of the country is that made at New Bedford, Mass., by Mr. Samuel Rodman and his son, covering the period from 1814 to within a year or so ago, a period of about ninety-five years. The following table shows the annual amount of precipitation during each year of the above-named period, from which one can see for himself the variations in the amounts from year to year, by the ten-year period, or make other comparison:

TABLE 1.—*Annual precipitation at New Bedford, Mass., for the period, 1814 to 1908.*

| Year. | Amount. | Year. | Amount. | Year. | Amount. | Year. | Amount. | Year. | Amount. |
|-------|---------|-------|---------|-------|---------|-------|---------|-------|---------|
| 1814  | 43.08   | 1833  | 42.62   | 1852  | 46.14   | 1871  | 49.60   | 1890  | 61.69   |
| 1815  | 40.78   | 1834  | 45.12   | 1853  | 39.47   | 1872  | 47.66   | 1891  | 47.83   |
| 1816  | 44.13   | 1835  | 47.21   | 1854  | 53.82   | 1873  | 51.70   | 1892  | 42.83   |
| 1817  | 43.33   | 1836  | 42.83   | 1855  | 41.00   | 1874  | 49.34   | 1893  | 50.27   |
| 1818  | 40.77   | 1837  | 39.07   | 1856  | 37.09   | 1875  | 48.33   | 1894  | 45.89   |
| 1819  | 39.66   | 1838  | 38.28   | 1857  | 43.30   | 1876  | 42.18   | 1895  | 41.63   |
| 1820  | 41.32   | 1839  | 44.38   | 1858  | 44.03   | 1877  | 47.04   | 1896  | 47.73   |
| 1821  | 45.64   | 1840  | 45.59   | 1859  | 51.43   | 1878  | 50.56   | 1897  | 50.96   |
| 1822  | 41.78   | 1841  | 50.60   | 1860  | 39.73   | 1879  | 42.31   | 1898  | 62.60   |
| 1823  | 59.89   | 1842  | 39.06   | 1861  | 46.46   | 1880  | 40.07   | 1899  | 44.34   |
| 1824  | 47.34   | 1843  | 50.67   | 1862  | 43.32   | 1881  | 39.10   | 1900  | 44.99   |
| 1825  | 38.09   | 1844  | 40.73   | 1863  | 45.10   | 1882  | 41.38   | 1901  | 51.84   |
| 1826  | 54.77   | 1845  | 48.06   | 1864  | 40.96   | 1883  | 43.51   | 1902  | 45.42   |
| 1827  | 62.90   | 1846  | 34.51   | 1865  | 46.01   | 1884  | 54.99   | 1903  | 47.49   |
| 1828  | 39.04   | 1847  | 45.91   | 1866  | 40.30   | 1885  | 36.81   | 1904  | 50.08   |
| 1829  | 65.41   | 1848  | 40.74   | 1867  | 47.11   | 1886  | 49.85   | 1905  | 41.30   |
| 1830  | 64.66   | 1849  | 36.42   | 1868  | 56.32   | 1887  | 51.77   | 1906  | 43.09   |
| 1831  | 61.18   | 1850  | 62.67   | 1869  | 49.94   | 1888  | 55.07   | 1907  | 42.32   |
| 1832  | 49.31   | 1851  | 51.61   | 1870  | 47.16   | 1889  | 52.71   | 1908  | 38.61   |

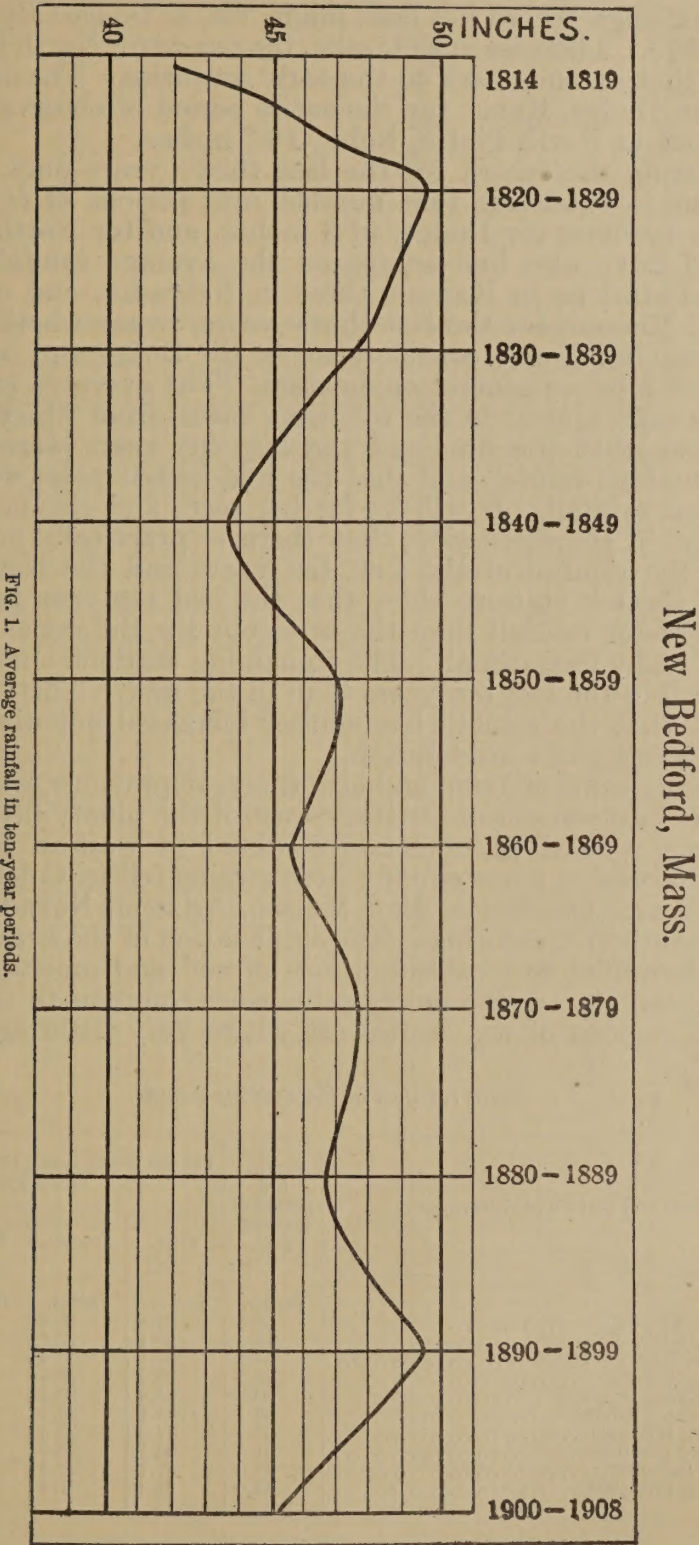
<sup>a</sup> The record for New Bedford ends with the year 1906; annual amounts for 1907 and 1908 are for Fall River, Mass.

The average fall for ten-year periods from 1814 to 1908, inclusive, indicates that while the rainfall during the past few years has been considerably less than the average, it has not been less than has occurred in numerous previous years—notably from 1814 to 1819, from 1833 to 1839, and from 1860 to 1866. Further investigation shows that for the first fifty years of the period the average annual rainfall at that point was about 46 inches, while during the last forty-five years the annual fall has increased to more than 47 inches. *This indicates that instead of a diminishing rainfall we have the evidence that, if there is any variation at all in the precipitation, it is a slight increase for this region.*

Figure 1 graphically shows the average fall for ten-year periods, namely, from 1814 to 1908, inclusive.

We will now move our inquiry to a part of the Middle West where there has been no deforestation. Here there has been a growth of planted hedge rows, of trees along highways and fence lines and about places of habitation, and the virgin soil has been broken and made more permeable to the rainfall.







In Kansas during the last fifty years records of rainfall have been made only in the eastern part of the State. In the western part of the State a single record has been made, viz, at Dodge City, extending back to 1875. Likewise in Nebraska, the record for North Platte is the only one that extends back to the early seventies. The mean annual rainfall at Dodge, Kans., for the entire period of observation is 20.8 inches, and at North Platte, Nebr., 18.7 inches.

Considering the record for the last thirty years only, since it is convenient to subdivide that number into periods of equal length, the mean becomes for Dodge, 21.3 inches, and for North Platte, 19 inches. I have also had computed the average rainfall for three additional stations in Kansas, three in Nebraska, and one each in Iowa and Missouri for the last thirty years, to see whether the conclusions reached from a consideration of the Dodge and North Platte data are of local or general application. The averages in periods of ten years each appear in the following table, from which it may be clearly seen that the first and the last ten years were periods of fairly abundant rainfall and that the middle ten years was a period of deficient rainfall. It will be further seen, and this is the important point in the discussion, that there is practically no difference between the rainfall of the first ten years and the last ten years. Three of the ten stations show that the last ten-year period had a slightly greater rainfall than the first, but the difference is so small that it is really immaterial. The remaining stations show a slightly less rainfall in the last ten years than in the first. This table shows, therefore, that the rainfall has neither increased nor diminished by amounts worthy of consideration.

The heavy rains of 1906, and also the year previous, were common to all that vast stretch of territory west of the ninety-fifth meridian. It was not a local phenomenon centered in western Kansas and western Nebraska, since equally heavy rains fell in Colorado, Utah, western Texas, Oklahoma, New Mexico, Arizona, Nevada, and central and southern California. The explanation of the heavy rains can not be attributed to local conditions of soil and moisture, since, as has just been stated, the heavy rains were common to the arid and mountain regions of the Southwest where very little agriculture is practiced.

*Mean rainfall at the stations named.*

| Stations and periods of observation. | For the full period of observation. | For the thirty years, 1877-1906, in periods of ten years. |                |                |                |
|--------------------------------------|-------------------------------------|-----------------------------------------------------------|----------------|----------------|----------------|
|                                      |                                     | First.                                                    | Second.        | Third.         | Mean.          |
|                                      | <i>Inches.</i>                      | <i>Inches.</i>                                            | <i>Inches.</i> | <i>Inches.</i> | <i>Inches.</i> |
| Dodge, Kans., 1875-1906.....         | 20.8                                | 22.8                                                      | 18.4           | 22.7           | 21.3           |
| North Platte, Nebr., 1875-1906.....  | 18.7                                | 20.1                                                      | 17.2           | 19.8           | 19.0           |
| Independence, Kans., 1872-1906.....  | 37.1                                | 39.1                                                      | 35.5           | 38.1           | 37.6           |
| Genoa, Nebr., 1875-1906.....         | 28.2                                | 26.3                                                      | 26.4           | 31.3           | 28.0           |
| Manhattan, Kans., 1858-1906.....     | 30.6                                | 33.4                                                      | 29.2           | 31.9           | 31.5           |
| Lawrence, Kans., 1868-1906.....      | 36.4                                | 35.1                                                      | 39.2           | 36.7           | 37.0           |
| Omaha, Nebr., 1871-1906.....         | 30.7                                | 37.6                                                      | 25.6           | 27.9           | 30.4           |
| Minden, Nebr., 1878-1906.....        | 31.5                                | 36.1                                                      | 29.2           | 29.8           | 31.7           |
| Oregon, Mo., 1866-1906.....          | 35.6                                | 37.1                                                      | 32.3           | 39.5           | 36.3           |
| Keokuk, Iowa, 1872-1906.....         | 35.0                                | 35.4                                                      | 31.4           | 35.1           | 34.3           |



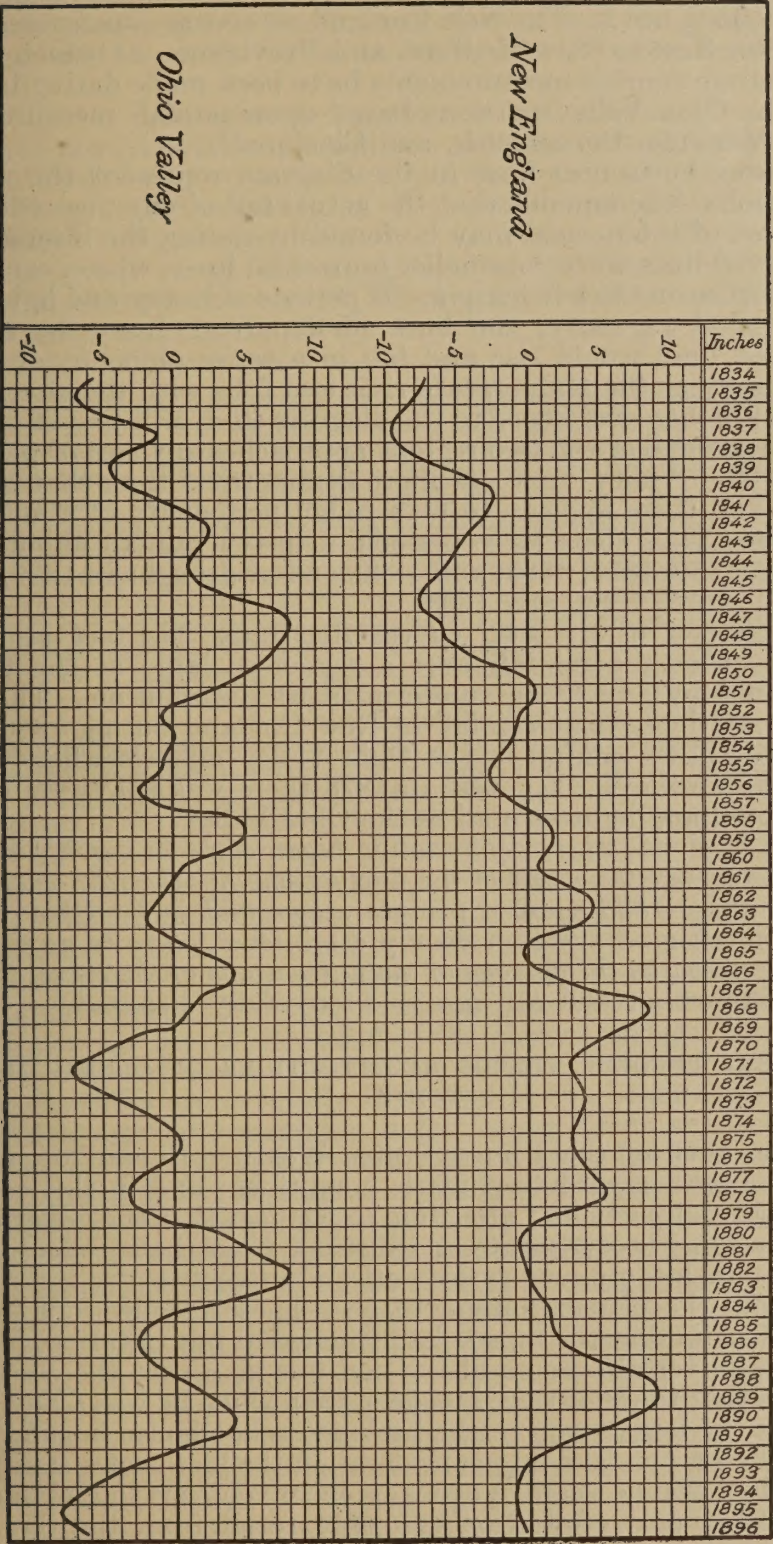


Fig. 2. Progressive Averages of Precipitation, 1834-1896.



The annual fluctuation in precipitation for two different parts of the United States, viz, New England and the Ohio Valley, is graphically shown in figure 2. The New England curve was constructed from the data for Boston, New Bedford, and Providence, at which points fairly accurate rainfall measurements have been made dating back to 1836. The Ohio Valley curve is based upon rainfall measurements made at Marietta, Portsmouth, and Cincinnati.

The heavy horizontal lines in the diagram represent the normal precipitation. The amount that the actual fall of any year exceeded or fell short of the normal may be found by noting the intersections of the curved lines with the smaller horizontal lines, whose values are given in inches on the left margin. If periods of heavy and light rainfall alternated regularly, the lines of departure from the normal (the curved line) would rise and fall in a series of bends or inflections precisely as the temperature rises and falls with the alternation of day and night. Reference to the diagram itself will best show how closely the rainfall of the two regions approaches any sort of periodicity. The Ohio Valley curve is more symmetrical than that of New England, and there appears to be a rough periodicity of about nine years in it. Thus there were periods of heavy rainfall about 1837, 1847, 1858, 1866, 1875, 1882, and 1890, and of drought in 1839, 1856, 1863, 1871, 1878, 1886, and 1895.

A comparison of the two curves illustrates the fact elsewhere referred to that the rainfall over a region so large as the United States is not by any means uniform in its distribution. Thus the period of relatively light rainfall in New England during 1880-1883 was one of heavy rainfall in the Ohio Valley and elsewhere in the great interior valleys. Likewise in 1878 there was heavy rainfall in New England and light rainfall in the Ohio Valley.

*In New England, where deforestation began early in our history and has been extensive, the mean of the fluctuations in the rain curve is a steady rise since 1836 up to a few years ago, and in the Ohio Valley, where the forest area has been greatly diminished, there is no decrease of rainfall shown by the average of the fluctuations of the curve. These facts are important and can not be successfully disputed.*

#### GOVERNMENT RECORDS VERSUS RECOLLECTIONS OF OLDEST INHABITANTS.

It is the duty of the United States Weather Bureau to publish information with regard to climatic conditions; and in this connection I would call particular attention to the fact that the government records are in a class separate and distinct from the recollections of the oldest inhabitants, which are entirely untrustworthy, no matter how truthful the persons intend to be. These recollections do not justify the claim that the forests have increased precipitation, for it is almost the universal opinion of the maturer man that the climate is milder and that the snows are less deep than when he was a boy. He remembers the long tramp to the little red schoolhouse in snow knee deep, but he fails to take into consideration the fact that a snow knee deep to a boy of nine years of age is no inconvenience to a man of six feet two. Human recollection can only recall from the dim past unusual storms—conditions that were abnormal, and these abnormalities are what the man of fifty or sixty years to-day believes to



have been the average when he was young. In other words, the individual recollection should be given little weight in determining a matter that requires careful calculation and the preservation of accurate daily records before anything like safe conclusions can be reached.

#### THE EFFECT OF FORESTS ON FLOODS.

I have always held to the opinion that the cutting away of forests has had little or no appreciable effect on the amount of precipitation or on the general temperature. But until recent years I did believe that deforestation had an important and beneficial effect on the conservation; that is, on the economical use of the rainfall, and that forests restricted the run-off. But study and investigation have caused me to modify my views.

Professor Abbe says:

The cultivated soil outside the forest, when plowed and broken open down to a depth of 8 inches, acts as a sponge to retain water quite as well as does the ordinary humus of a forest, especially when we consider that under a forest less rain actually enters the humus. In fact such measurements as have been made show that the amount of water that is eventually given up from the forest humus varies but little from that given up in the course of time by the unforested, cultivated soil. The total run-off from the two regions does not eventually differ greatly, but it does differ in the speed. However, it may be neither the amount nor the speed of run-off from the soil that determines the occurrence of river floods. We must distinguish between the soil run-off and the river run-off. When water has once entered the river channel its movements are determined wholly by the force of gravity, the curvature, the section, and the slope of the channel. Floods may occur in every small tributary and yet these waters may so enter the main channel as to produce only a gentle rise throughout its whole length. At other times the smaller elementary floods may conspire and produce a specially disastrous flood in the main channel. Therefore the occurrence of disastrous floods does not depend on rainfall alone or wholly on soil run-off, but equally and principally on the relative times at which floods occur in the individual tributaries, and the time required by them all to reach and combine at any given point in the main channel.

This is a tangled problem, since the result must depend upon the slope of the ground; the nature and condition of the soil; the nature of the forest, whether deciduous or evergreen; the nature of the general climate of the place, whether it has cold, snowy winters or rainy ones, and whether the spring merges gradually or abruptly into summer; upon the use or treatment of the cleared surface; and probably upon other conditions.

The foresters are generally in accord in the belief that the forests exercise a marked restraining influence on floods and a conserving influence on precipitation, even if they do not actually increase, by an appreciable amount, the rainfall. On the other side, army and civilian engineers and meteorologists generally believe that the broken, cultivated, permeable soil, which is covered for a greater portion of each year with millions of the rootlets of growing grasses and cereals, is equally as good a conservor of the rainfall as the forest area itself, even though the latter has the advantage of the deep boring of large roots into the substratum; that the evergreen forests prevent the drifting of the snow and at the same time their heavy foliage protects the snow from the sun and permits a slow melting, which is all absorbed by the forest cover until it is saturated, and then with further heat the water breaks out in a flood; that the function of deciduous forest trees is to catch the falling snow, distribute it equally over the surface, and thus facilitate more rapid melting by causing the snow to present to the warm air a greater melting surface than it does in the



open, where wind drifts it into banks in the lee of opposing objects and stores it in depressions and ravines, so that it may remain for a considerable time after the evenly distributed blanket has disappeared from the forests.

It has been shown by Chittenden that in Yellowstone Park and similar mountain regions the forests protect the snow from drifting, melting, and evaporating, while in the open there is much drifting and an early clearing up of those places well exposed to wind and to sunshine; therefore, when warm weather and its rain come on abruptly, and come to stay for the summer, as they do in those regions, the melting of the snow in the forests, because of the greater area exposed, the surface being uniformly covered, is far more rapid than it is in the open where it is badly drifted, and leads to higher freshets and less enduring run-offs. *On the whole, it is probable that forests have little to do with the height of floods in main tributaries and principal streams, since they occur only as the result of extensive and heavy rains, after the ground is everywhere saturated, or when heavy warm rains come on the top of deep snows.*

#### RUN-OFF AND ABSORPTION.

Concerning the surface run-off, it appears to be generally held that when the rainfall is small, the dead leaves, the moss, the tangle of undergrowth, and the like, in the forests may modify or entirely prevent flow, and may slightly intensify low-water conditions of summer, while on the cleared surfaces, except that of freshly-cultivated fields, this is not so markedly the case. When the rains are heavy and continued, there is surface flow in the forests as well as in the open, and the two do not materially differ, for it can be shown that the run-off from a smooth surface and from one covered with sticks, dense grasses, or forest, are equal after the rough surface becomes saturated, and it is long after *all surfaces* have become saturated that flood conditions can occur.

Because of their open, porous condition sandy soils and freshly plowed fields are the best absorbers, and in general forest ground is thought to be more penetrable to moisture than is that of the cleared fields, except when the latter are freshly broken, but the greater part of the cleared land is either broken and cultivated several times during the year or else it is occupied by vegetation that exercises either partly or wholly as great a conserving influence as the forest.

All of these problems could be definitely settled beyond the possibility of argument if we had accurate river gaugings from day to day and year to year, together with a full knowledge of the rainfall and of the proportion of the wooded to cleared areas, data that unfortunately we do not have. We must, therefore, reason empirically from the best information at hand, and this insufficiency of data renders less positive the conclusions of all investigators, no matter which side of the question they may be on.

#### EFFECT OF FORESTS ON FLOODS IN FRANCE.

An important contribution to this discussion was made in 1873 by Capt. Charles J. Allen, of the Engineer Corps, U. S. Army, in the translation that he made of extracts from the work of M. F. Vallès, which treats of the influence of forests on floods and inundations.



This translation contains quotations from the works of M. Belgrand and other French engineers, who had made the hydrology of the basin of the Seine a special study.<sup>a</sup> Among other things M. Belgrand says:

This country comprises all or part of 21 Departments, as follows: Aisne, Ardennes, Aube, Cote d'Or, Eure, Eure-et-Loire, Loiret, Marne, Haute-Marne, Nièvre, Nord, Oise, Pas-de-Calais, Seine, Seine-Inferieure, Seine-et-Marne, Somme, Vosges, and Yonne, and comprises an area of about 107,000 square kilometers, nearly equal to the fifth part of the area of country comprising the 86 Departments.

The most irregular streams, those most subject to rapid rises, are found especially in the Departments of the Yonne, Nièvre, and Cote d'Or, and to a less extent in those of the Aube, Haute-Marne, and Aisne. This region is very woody, more so, perhaps, than the rest of France. The most remarkable Departments in regard to the regularity of the water courses which rise within them are the Eure, Eure-et-Loire, Nord, Oise, Pas-de-Calais, Seine-Inferieure, Somme, the chalky parts of the Aube and of the Marne, and those portions of the Seine-et-Oise and Loiret in which the limestones of La Beauce abound. The majority of the streams in these countries are subject to slight rises of short duration, their stage of water varying but little. This group of Departments is perhaps one of the most sparsely wooded in France, because the Eure, Eure-et-Loire, Nord, Oise, Pas-de-Calais, Seine-Inferieure, and the Somme have only about one-tenth of their surface wooded, and the plateaus of La Beauce and the chalky plains of Champagne are, if we except some recent plantations of pine, completely bare of trees.

In order to test the question as to the effect of forests in regulating the flow of water M. Belgrand had daily measurements made from November, 1850, to May, 1853, of the discharges of the Cousin and of the Grenetierre, which is one of its affluents. Both of these basins are of granite formation, impermeable and otherwise alike, but the first is only about one-third wooded, while the second is entirely covered with trees. Notwithstanding this great difference as regards the extent of forests in each, the results have been the same in both, as is shown by the following account:

"The regimen of each is identically the same, although their valleys are unequally wooded. Their waters rise and fall at the same rate, whether in rainy weather or in dry, in winter or in summer; their low winter regimen is more abundant than that of summer.

"A heavy rain in winter produces in both a sudden flood of greater or less height, but of very short duration, followed by a long stage of tolerably high water; the sudden and high freshets take place in each at the same time."

The different details concerning the flow of water are, then, exactly the same in the two basins, and yet one is entirely covered with forests, while in the other two-thirds is bare of trees. M. Belgrand has made a number of more detailed observations yet, which show, further, that it is not upon forests but upon cultivated ground that the greatest regularity in flowage is observed. \* \* \*

In Vallès's paper he quotes from a report on the basin of the Eure made by M. St. Clair, engineer in chief, showing the beneficial effects of cleared and cultivated lands in diminishing by absorption the amount of surface water, as follows:

All the valleys, even those of least extent, are cut up by ravines which were often formerly the beds of torrents. Within the last twelve years the condition has changed; they are now almost always dry. The cause of this great change, the progress of agriculture, is generally recognized in the country. The soil has been cultivated more and rendered more permeable; the farmers, reaping more advantages from the culture of the ground, and fully aware of the utility of improving it, have, by means of ditches, hedges, and endikements properly located, controlled the flow of water everywhere, preventing erosion, causing fertilizing deposits of sediment, and relieving the surface of the ground from the asperities which interfered with cultivation. The waters, retarded thus in their flow, have settled in great part through the ground and disappeared before reaching the ravines.

These agricultural improvements, in a country where land susceptible of cultivation, amounts to sixty-one one-hundredths of the area of the country, have, then, reduced the surface flowage and increased the absorption.

<sup>a</sup> Annales des Ponts et Chaussées, année 1852, premier semestre, p. 102.



They have rendered less frequent and formidable the freshets, which, in the basin of the Eure, are to be attributed to an excess of surface water rather than to any supply from springs, which latter is almost always invariable.

The effect upon springs of cutting down forests can now be easily eliminated. We will divide them into two classes, viz, superficial and subterranean.

The first issue from the points of the surface very near to the strata in which the waters which produce them collect. The second, on the contrary, are found very far below these strata, and the water, in order to find an outlet, traverses frequently long distances underground.

The first, generally small, pertain indifferently to absorbent or nonabsorbent ground; but the second, occasionally very powerful, pertain essentially and almost exclusively to permeable soils.

Now, it is indisputable that the continual humidity of the soil of forests is favorable to the first and ought to maintain in their feeble flow considerable regularity. It is, then, very likely that the clearing away of forests and exposing the earth to alternations of drought and moisture would alter the regimen of these springs; that these would be more abundant in time of rain; that they would decrease in summer and possibly be dry for several months in the year. This explains the disappearance of certain springs after the cutting down of forests.

As regards the second group, which are plentifully supplied by infiltration through the permeable soils, it is different.

From the different manner in which, as regards absorption, wooded and cultivated soils act, we see that in the first this faculty is in great part destroyed, while in the second it is increased. To remove standing timber from permeable soils is to restore to them the facility of transmitting the waters which the forest vegetation, whether by the spreading of its roots, by the fall of leaves, or by the compactness of the soil, had taken from them, and it results, consequently, in a more abundant supply of water to the subterranean springs.

Thus, it is worthy of remark that the most abundant of all of them, especially in seasons of low water, are located beneath the vast ledges of limestone which are almost entirely denuded; for instance, those of Cahors and Louysse, in the department du Lot, and the famous fountain of Vaucluse, of which mention has already been made.

M. Belgrand further says:

Now these basins, so remarkably alike, we have; they are those of the Seine in the seventeenth, eighteenth, and nineteenth centuries. Everything in these is alike excepting the extent of the forests, which has steadily decreased, so that if we were in possession of adequate information of some exact measurements of the greatest inundations during the time specified, we could easily test the correctness of our theories.

In fact, observations of this nature have been made; they go back to 1615, about the time when French industry began to develop, and when, consequently, the felling of timber to a great extent commenced.

This places at our disposal an interval of five half centuries.

In a memoir published in 1814 by the engineer Egault, these observations were compiled, discussed, and arranged with reference to the heights of the most marked inundations. We add to the results collated by them those which have been obtained since his time and give them in the following table:

| Dates of the inundations. | Height at the bridge of La Tour-nelle. | Mean per half century. |
|---------------------------|----------------------------------------|------------------------|
|                           | <i>Feet.</i>                           | <i>Feet.</i>           |
| July 11, 1615.....        | 29.99                                  | 27.53                  |
| January, 1649.....        | 25.10                                  |                        |
| January, 1651.....        | 25.59                                  | 26.36                  |
| March 1, 1658.....        | 28.87                                  |                        |
| March, 1690.....          | 24.61                                  | 25.34                  |
| March, 1711.....          | 24.77                                  |                        |
| December 25, 1740.....    | 25.92                                  | 22.42                  |
| January, 1751.....        | 21.98                                  |                        |
| November 14, 1764.....    | 22.97                                  | 21.22                  |
| March 4, 1784.....        | 21.85                                  |                        |
| February 4, 1799.....     | 22.87                                  | 21.22                  |
| January 3, 1802.....      | 24.44                                  |                        |
| March 3, 1807.....        | 21.85                                  | 21.22                  |
| May, 1836.....            | 18.66                                  |                        |
| February, 1850.....       | 19.91                                  |                        |



The deductions from this table are striking. The continued decrease of the floods for each half century is remarkable. The waters attained a mean height of 27.53 feet in the first half of the seventeenth century; they only attained a mean of 21.22 feet in the present. According to this, we have experienced an amelioration of nearly 6.56 feet, and yet the trees have been steadily and unceasingly cut down, and the forests transformed into cultivated farms.

What would we gain, then, to-day, I ask, in rewooding our field? It would be but an unfortunate attempt to restore the old order of things, when the floods of the Seine rose to 29.53 feet above the low stage.

In connection with the conclusions reached in this report, as well as with regard to those reached by the foresters and others who differ from my views, I would emphasize the fact that none of us have flood data extending over any great period of time, but in Europe we fortunately have some long-period observations. The preceding pages show the result of observations made by competent engineers during two and one-half centuries in the basin of the Seine, and show that there has been a gradual and constant decrease in the height of floods with the diminution of forests.

In Germany another long-period record is presented. Mr. Ernest Lauder, chief of the hydrographic bureau of the Austrian Government, recently made an exhaustive investigation of the records of the Danube, the great river of central Europe. He prepared an exhaustive report on the destructive floods in the Danube that occurred in 1897 and 1899, and in this report traces the history of the floods of the Danube for eight hundred years, taking into account 125 different floods. His conclusions are that progressive deforestation of the country has had no effect in increasing the frequency of floods or in augmenting their height. Among other things he showed that the flood of 1899, which was a summer flood, was severest where it came from the heavily wooded districts.

Much has been written about the barren condition of the valley of the Jordan, in the Holy Land, and it is pointed out that great cities and teeming populations once covered the regions now barren; but this does not prove that if there has been a decrease in the rainfall it is due to deforestation, for everywhere in this region are evidences of extensive irrigation that was practised at the time this region was thickly populated. The date palm, the vine, and the fig tree will grow there as luxuriantly to-day as in the old Biblical days, if artificial irrigation is used, as was formerly done. It is not believed that the cutting of the cedars of Lebanon has had anything to do with the dryness of the adjacent regions.

At the tenth International Congress of Irrigation, held at Milan in 1905, papers were presented by representatives from France, Germany, Italy, Austria, and Russia, in which the writers heartily favored the protection of the forests and their cultivation. But these writers were unanimous in the opinion that forests exercise little influence upon either the high water or the low water of rivers.

In this connection I will quote from Col. H. M. Chittenden, M. Am. Soc. C. E., volume 34, page 944, Proceedings of the Society of Civil Engineers, as follows:

The constantly reiterated statement that floods are increasing in frequency and intensity, as compared with former times, has nothing to support it. There are, it is true, periods when floods are more frequent than at others, and hasty conclusions are always drawn at such times; but, taking the records year after year for considerable periods, no change worth considering is discoverable. The explanation of these periods of high water, like the one now prevailing, must, of course, be sought in pre-



cipitation. That is where floods come from, and it is very strange that those who are looking so eagerly for a cause of these floods jump at an indirect cause and leave the direct one entirely untouched. In the records of precipitation, wherever they exist, will be found a full and complete explanation of every one of the floods that have seemed unusually frequent and severe in recent years.

#### THE SOURCE OF FLOOD WATERS IN THE UNITED STATES.

Before one can get a comprehensive idea of the magnitude of the problem involved in the creation of the floods of the United States, it will be necessary for him to first study chart A, which gives a typical illustration of the cyclonic storms that frequently form on the Rocky Mountain Plateau, either on its northern, central, or southern portions. Under the influence of gravity air flows from regions where the pressure is great toward the regions where it is less. In the case illustrated by this chart the atmosphere, as indicated by the direction in which the arrows point, is flowing from the region marked "high," which is central over the Carolinas, toward the region where the pressure is low, which is central over Montana, and the vaporous atmosphere that rises from the Gulf of Mexico and the adjacent ocean is carried far into the interior of the continent. Conditions similar to these occur many times each month, and as a result the eastern and central portions of the United States are bathed in a succession of rains which, as shown by chart B, gradually thin out and largely disappear on the eastward edge of the Rocky Mountain Plateau, because the currents of air from the Gulf of Mexico do not reach farther inland.

#### STATEMENT BY MR. BAILEY WILLIS.

In the May issue, 1909, of the magazine entitled "Conservation," page 262, Mr. Bailey Willis makes the statement:

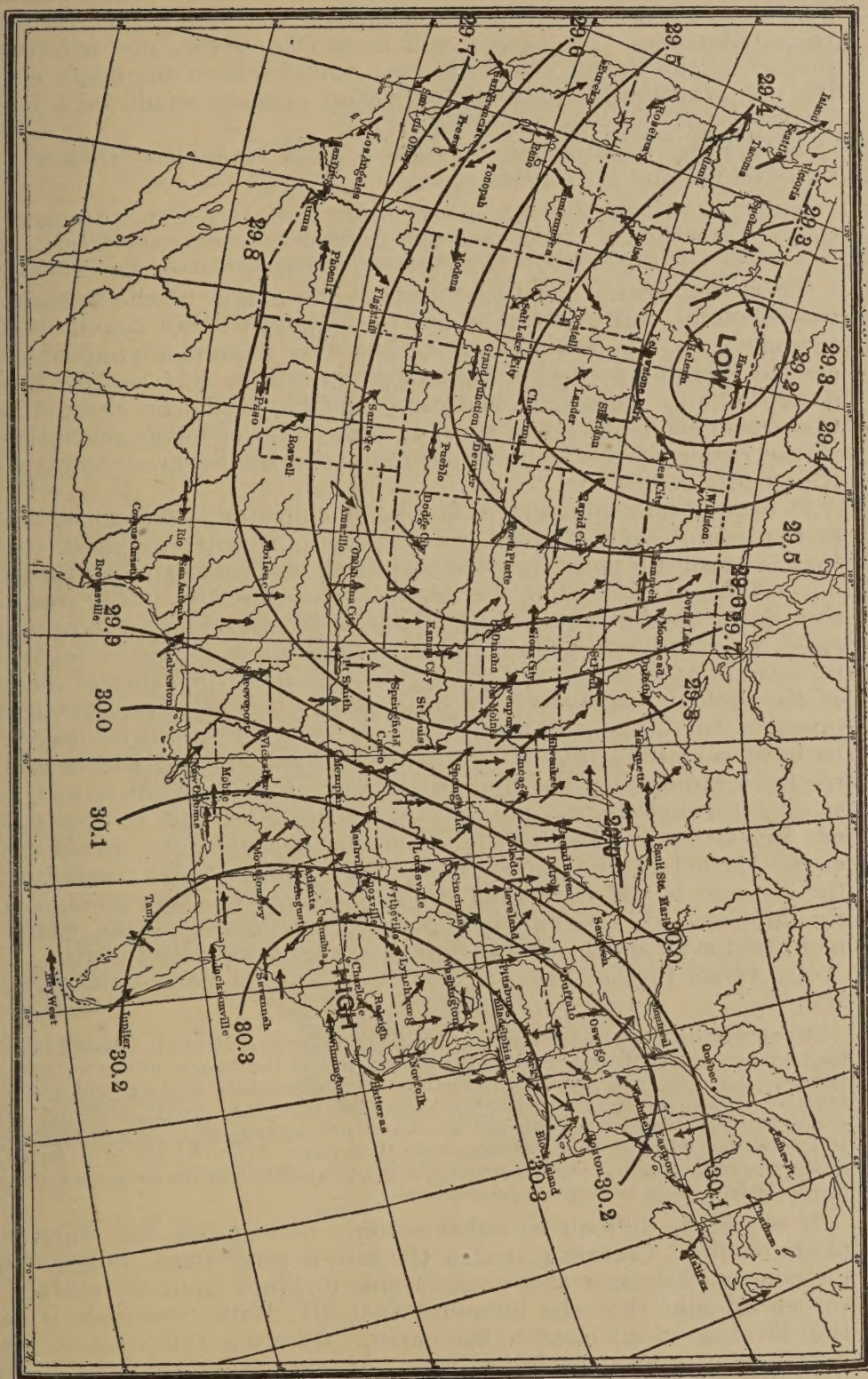
The moisture which falls upon North America in the form of rain and snow comes chiefly from the Pacific Ocean. A smaller proportion, rising from the Gulf of Mexico and the West Indian seas, falls upon the eastern United States.

It is true that chart B, giving the normal annual precipitation indicates that the Pacific Ocean furnishes precipitation that is heavy along the immediate coast, but that it is the principal source, as Mr Willis says, of the moisture that falls upon the North American Continent, is not borne out by the facts exhibited by the precipitation chart herein produced and by the inflowing currents of air that are shown on chart A.

The range of mountains on the Pacific coast intercepts the inflow of the vaporous atmosphere, which is comparatively shallow, and precipitates its aqueous vapor on the windward side of the range, and mainly on the north half of the windward side, because storms seldom enter from the southern half. To be sure, some of the scant precipitation that falls on the plateau does drift over the tops of these mountains, but the amount is small. Certain it is that the Pacific Ocean has little influence on the precipitation of the eastern half of the United States, which fact is well understood by meteorologists; and I believe that most of them will join me in the belief that the only way that man could materially affect the rainfall of the eastern half of the United States would be to erect a mountain barrier



CHART A.—Arrows fly with the wind and show how the vaporous atmosphere of the Gulf of Mexico and the South Atlantic Ocean is drawn inland.





10,000 feet high skirting the Gulf and South Atlantic coasts. Of course this is impossible, but if nature had erected it there would be no question about floods in the Ohio and the Mississippi rivers and their tributaries, for there would be neither rivers nor tributaries; just as on the Pacific coast, the rain would fall on the ocean side of the mountains, and the world's greatest granary would be a barren waste.

Prof. Frank H. Bigelow, on page 17 of *A Manual for Observers in Climatology and Evaporation*, says:

All this distribution of the general circulating currents, and the consequent precipitation, would occur whether there were forests or not growing on the land masses. It may be proper to say that the forests follow the precipitation and do not precede it.

There can be no question but that the action of the sun on the waters of the Gulf of Mexico and the adjacent ocean heavily charge the air with water vapor, and that this vaporous atmosphere is carried inland by the circulation of the air in such storms as are described in a preceding paragraph and illustrated on chart A, and that the effect is shown on chart B in the form of heavy precipitation in the region of the Gulf, which gradually shades away toward the Rocky Mountains.

It is therefore apparent that the precipitation that causes floods in the eastern half of the United States is from the aqueous vapor that is raised up from the vast waters to the south and southeast of our continent, and that *the supply is inexhaustible. Our rainfall, then, is the result of such fundamentally great causes as not to be appreciably affected by the planting or cutting away of forests, or by any of the operations of man in changing the character of the surface covering of the continent*, although to statistically and positively settle the question beyond the possibility of argument it would be necessary to have scientific data of temperature, rainfall, and the height of rivers, beginning at the first settlement of the continent and continuing through to the present time. Such records, of course, are not in existence. But the fundamental fact that the precipitation of the United States is due to the great hemispherical circulation of the air, and to the relation of the great bodies of water to land, and the direction of the vapor-bearing currents, and the trend of mountain systems is something that can be positively shown.

Mr. Willis further says, in the same issue of *Conservation*, page 265, that:

The mountains are wet because they are high, and they are heavily forested because they are wet. But there is also a reciprocal action of the forests on the wetness, for the radiation from the dark-green expanse is comparatively uniform and promotes frequent and steady rains. Were the mountains bare they would, like the bared sierras of Spain, receive occasional but violent downpours and send down excessive and disastrous floods, even more disastrous than now. \* \* \* For in so far as we clothe the surface with green crops we lower the temperature of the rising air and favor precipitation on the verdure-covered plain.

It would be difficult to either confirm or disprove this statement of Mr. Willis. Certain it is that the rain is precipitated largely from air masses that exist at a considerable distance from the surface of the earth, and that the influence that Mr. Willis describes is in a thin stratum of air close to the earth. Rarely is this stratum saturated, even during the fall of rain. If, then, the processes that he describes do not bring the air to the saturation point, and if the



CHART B.—Annual precipitation.





precipitation occurs in the regions above those affected by these local surface conditions, I am unable to see how the rain can be either increased or decreased in its amount. Certain it is that most of the leading meteorologists of the world are of the opinion that the rainfall on continents is caused by the fundamentally great operations of nature as described above.

#### EROSION.

Another effect of deforestation, that of erosion, is of importance, but of unequal importance in different sections. In level countries it makes but little difference in this particular whether the ground is waste, cultivated, or densely forested, while in hilly or mountainous sections the result is different. When the soil becomes well sodded with grass, erosion is little worse in fields than in the woods, but usually the fields are cultivated from time to time, and occasions come when the best of care and cultivation can not prevent the formation of bad gullies that injure both the gullied fields and those of the lower grounds that are overflowed.

Of course, though, a field with an occasional wash yields more food material than the same area covered by a forest of any kind, so that only in exceptional cases—those in which erosion would probably be unavoidable and ruinous—is this a sufficient argument against clearing away the woods and the planting of crops in their stead, *for the time is come when we should not only increase the yield per acre by wise rotation of crops on cultivated ground, but clear up and seed to wheat, corn, grass, and fruits millions of acres that now lie idle under brush or forest.* In other words, every acre that will grow food for the people, and thereby reduce its cost and furnish sustenance for our increasing population and the teeming millions that are on the way to these shores, should be so employed; the remainder should grow timber that should be protected in its growth. Man and beast love the cooling shade, and the eye is pleased by the beauty of the wooded landscape. Therefore begin with the children and teach them to plant trees along the highways and byways and on the barren spots that will not produce food. Thus may we approach this problem rationally, with the object of gaining the greatest good for the greatest number for the longest period of time.

#### RATIO OF THE FORESTED AREA, OR MOUNTAIN WATERSHEDS, TO THE TOTAL WATERSHED.

I am of the opinion that not enough consideration has been given to the relative magnitude of the areas involved in the creation of floods. A flood in any given stream is usually caused by the precipitation over its entire watershed or over those of the major tributaries and is affected but comparatively little in a region like that of the Ohio basin by the precipitation over the extreme upper reaches, usually the forested area, or any other area that could be reforested without seriously encroaching upon the rich alluvial plains.

A critical examination of Chart C, which shows the entire river system of the Ohio basin and gives the exact limits of its boundaries, and which also indicates the elevations, shows what a comparatively small area in relation to the total catchment basin lies at











elevations of more than 1,000 or 1,500 feet above sea level. This chart furnishes a conclusive answer to those who believe that floods, except, of course, torrents in the mountain creeks, are caused by the precipitation on the comparatively small area of the watersheds at the headwaters of rivers. If it be granted that forests control the flow of streams, and I doubt that they do except as stated above, it will be necessary, in order to have an appreciable effect on navigable or other important rivers, to reforest areas many times in excess of anything that so far have been contemplated. *The rugged mountain slopes and tops, where land has little value, are unimportant as flood producers. It will be necessary actually to reforest the lower slopes and valleys where the land is of great value and where it should be devoted to agricultural purposes.* I can not escape this conclusion.

#### ARE FLOODS INCREASING?

Two papers have recently appeared, in both of which the argument is made that there is a marked tendency toward increasing flood frequency as a result of deforestation. The first of these papers in point of time was that of Mr. M. O. Leighton, Chief Hydrographer United States Geological Survey.<sup>a</sup> The second paper appeared in volume 2, Senate Document No. 676, beginning at page 112, and later as Forest Service Circular No. 176, January 11, 1910, under the signatures of Mr. William L. Hall, Assistant Forester, and Mr. Hu Maxwell, expert.

Before entering upon a discussion of these papers I wish to draw attention to the following statement in the last-named paper, page 3:

\* \* \* Both the Geological Survey and the Forest Service *have secured data,*<sup>b</sup> and the results warrant the statement that unmistakably floods are steadily on the increase in some of our most important rivers.

I wish to remark in connection with this statement that substantially all of the data used by the authors of the papers above mentioned were drawn from the records of the United States Weather Bureau.<sup>c</sup>

In Water-Supply Paper No. 234 the author has made a diagrammatic arrangement of data composed of annual and decennial means, whereby he shows an apparent progressive increase in the number of flood days at Wheeling, W. Va., and other points, without a proportionate increase in the amount of precipitation. It appears to me that his argument is defective in at least two particulars.

First. The flood or danger stage of the rivers at the various places discussed by him was long ago fixed by the Weather Bureau as being at the point where the river either overflows its banks or damages property adjacent thereto. Mr. Leighton has disregarded these points and arbitrarily assumed, for the purpose of his discussion, a

<sup>a</sup> Report of National Conservation Commission, p. 95, and Water-Supply Paper No. 234.

<sup>b</sup> The italics are mine. (Author.)

<sup>c</sup> In Water-Supply Paper No. 234 the impression seems to be given that the author's researches and conclusions are based on a consideration of river discharge measurements. It is proper to state that river discharge measurements were begun under the direction of the United States Geological Survey in 1896 and that gauge readings of heights of rivers were begun by the United States Signal Service, now Weather Bureau, in 1874.



considerably lower stage in each case, so that his argument fails completely so far as it relates to flood frequency; for example, at Wheeling, W. Va., he assumes a stage of 20 feet, whereas the Ohio at that point is not in flood until a stage of 36 feet is reached. What the author is discussing is therefore not floods as such, but moderate stages of the river.

What appears to me to be a second defect in the author's argument lies in his acceptance of the total number of so-called flood days (20 feet or more being a day of flood) divided by the annual precipitation as an indication of flood intensity, since the annual rainfall, as he himself acknowledges,<sup>a</sup> bears little or no relation to floods. Greater floods may occur during a year of deficient precipitation than during one of excessive annual precipitation if the proper proportion of the rainfall be concentrated over a limited area in a limited time.

An examination of the data for Chattanooga, Tenn., given by that author, discloses the fact that there has not been any increase in the number of so-called flood days at that place. The average amount of precipitation for each daily river stage of 20 feet or more, as determined by him, is almost exactly the same for the two periods, 1884 to 1895 and 1896 to 1907, inclusive. But in the number of *actual flood days*, as determined by Professor Frankenfield, the official in charge of the Weather Bureau river and flood service, that is, 33 feet or over (and the river does not reach the danger or flood stage until it stands 33 feet above low water), there was a considerable decrease in the second period, in harmony with the precipitation.

I understand that when Mr. Leighton speaks of "the ratio of the annual number of days of flood to annual precipitation," he means the number of days (stage above 20 feet) in each year divided by the *total* precipitation for the year. Thus, if the number of flood days in any one year is 20, and the total precipitation is 40 inches, the ratio would be 20 divided by 40, or 0.5. These ratios are totaled in eleven-year periods and the average of each period obtained. The average for the first eleven years, as obtained by him, was 0.38, and of the second, 0.48, indicating, in his opinion, an increase in flood intensity during the second eleven-year period, as 1 inch of rain made only 0.38 of a flood during the first period, while in the second period 1 inch of rain made 0.48 of a flood. In other words, during the first eleven-year period 1 inch of rain made only 38 per cent of 20 feet of water, or 7.6 feet; while during the second period 1 inch of rain made 48 per cent of 20 feet of water, or 9.6 feet.

This line of reasoning leads to wrong conclusions, as it is certain that the ratios obtained by dividing the number of days that a certain gage reading was reached or maintained by the annual, or for that matter by any other, precipitation, without entering into the problem the exact height of water gives a meaningless result. It appears to me to be a fatal method of reasoning to take simply the number of days that a stage of 20 feet was reached, without regard to heights above 20 feet. Therefore, if on a certain number of days the gage reading was exactly 20 feet, one would get precisely the same quotient as he would if on the same number of days the gage readings were largely in excess of 20 feet.

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<sup>a</sup> Page 22, Water-Supply Paper No. 234.



I now come to that part of the discussion in Water-Supply Paper No. 234 which has been widely quoted by the adherents of the forest-control idea, viz, the proposition that, although the flood periods in the Tennessee have decreased in later years due to diminished precipitation, the flood tendencies have increased. This idea, like others that have been put forward in this connection, is important if it can be substantiated; and if it is proven, then it is incumbent upon the author of that paper to show that the increase is due to deforestation, which he does not do. I have no data as to the area that has been cleared or that has been allowed to revert to forests, but it can not be great in twelve years.

This whole matter of the influence of forests upon climate and floods is so important to the nation in planning a correct economic policy for the future that we should move cautiously and be sure that we are building safely and wisely. I am heart and soul with the noble men and women who, as individuals or collectively, are striving to protect and conserve in the interests of the whole people the nation's resources of forest and field and of minerals and water power, and in this opinion I am generally and strongly sustained by the scientific staff of the Weather Bureau.

With regard to the matters of which this paper specifically treats I wish for the freest, fullest, and fairest discussion and investigation, with the end in view of correcting error if there be such and of finding common ground upon which all well-meaning persons may stand. Those whose official reports differ from mine I believe to be as honest and as sincere in their investigations and conclusions as I know myself to be.

To return to Supply Paper No. 234, referred to above, I quote as follows from page 23:

The results for the Tennessee basin cover twenty-four years, from 1884 to 1907, inclusive. \* \* \* Summing up the flood-producing rains for the twenty-four year period, it is found that the total is 335, of which 313 occurred from December to May, inclusive, and the remaining 22 during the other portion of the year. It is apparent that the number of such rains from June to November is not sufficient to afford a basis of comparison. Therefore only the December to May floods will be considered. \* \* \* On dividing the period covered by these 313 floods equally, two consecutive twelve-year periods are afforded, which give a basis of comparison. The floods in the later period, resulting from a given depth of storm precipitation, are clearly shown to be more severe than in the earlier period. The method of presentation further makes it possible to compute the increase in flood tendency due to deforestation in the Tennessee.

\* \* \* \* \*

If we now divide the number of flood days by the number of storms the result will be the number of days per storm.

*Days of flood per storm.*

| Period.                  | Storms in inches precipitated. |           |           |           |           |           |           |           |
|--------------------------|--------------------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
|                          | 1 to 1.5.                      | 1.5 to 2. | 2 to 2.5. | 2.5 to 3. | 3 to 3.5. | 3.5 to 4. | 4 to 4.5. | 4.5 to 5. |
| 1884-1895.....           | 0.7                            | 0.5       | 2.5       | 1.8       | 2.6       | 5         | 6         | 8.1       |
| 1896-1907.....           | .4                             | .9        | 2.6       | 2.7       | 3.2       | 6         | 8         | 6.7       |
| Percentage Increase..... | - 43                           | 80        | 4         | 50        | 22        | 20        | 33        | - 17      |

The algebraic sum of the above percentages is 149 and the average is 18.75, which sums up the effects of deforestation on run-off from 1884 to 1907, inclusive.



I invite attention to the figures given in this table "Days of flood per storm." If the run-off in the second period was greater than in the first, due to deforestation, would not the latter show a uniform and progressive influence increasing as the amount of rainfall increased? How, then, does it happen that a decrease in run-off of 43 per cent is shown for rains of intensity 1 inch to 1.5 inches, while in the next higher grade of intensity, viz, 1.5 to 2 inches, an increase of 80 per cent is shown? In the next higher grade, viz, 2 to 2.5 inches, the increase drops to 4 per cent. These results founded, in my judgment, on incorrect premises, are both inconsistent and meaningless. To "divide the number of flood days by the number of storms" gives no valuable quotient; for the gage readings selected as floods are not floods, but only moderate stages, and no account is taken of the actual height of the water, and while the conclusion is reached that there is an increase in flood intensity of 18.75 per cent in the Tennessee basin in the past twelve years due to deforestation, no records or other evidence are presented that there is not as much forest area in this basin as there was twelve years ago; or that, if there is a decrease, it would be sufficient to account for such a large increase in flood intensity.

But—and here is the most important matter in the consideration of Mr. Leighton's conclusions—no matter how complete the data may be, or how fundamentally sound and fair its collation and grouping, the comparison, the one with the other, of such short periods as those measured by only twelve years, can not give results with regard to changes in climate and floods that will permit the most skilled meteorologist or engineer to draw fundamental conclusions that can have any value. Precisely the same amount of rain falling in the two periods and no change whatever in forest or cultivated area might produce largely differing results on floods, depending on the sequence with which it fell over the different tributaries and how it was concentrated or scattered, and on many other complicated conditions of run-off, such as the coinciding of the flood volume from one tributary with that of another, instead of each passing down the main stream at different times.

There is also the difficulty of securing accurate precipitation data. Whenever the height of the gage is altered or other change made in its environment that disturbs the flow of the air currents the readings of one period may not fairly be compared the one with the other. These defects vitiate the precipitation data of many stations of the Weather Bureau, especially those in large and growing cities, and can only be remedied by the Government controlling for a long period of years an area at each station so large that it can determine the exposure and keep it constant.

*Another way of comparing the precipitation and the river stages of the Tennessee basins.*—I give in the following table the rainfall at Chattanooga and Knoxville separately for the months December to May, inclusive, for each of the twenty-four years considered in Water-Supply Paper No. 234; also the total number of days of river stages of 20 feet and above on the Chattanooga gage. The rainfall so tabulated includes only the heavy rains, and the arrangement according to intensity is precisely the same as that followed in Water-Supply Paper No. 234.



*Heavy rains at Chattanooga and Knoxville, Tenn., during six months of each year (December, 1883, to May, 1907).*

| December-May, 1883-1907. | 1 to 1.5 inches. |               | 1.5 to 2 inches. |               | 2 to 2.5 inches. |               | 2.5 to 3 inches. |               |
|--------------------------|------------------|---------------|------------------|---------------|------------------|---------------|------------------|---------------|
|                          | Number of rains. | Total amount. | Number of rains. | Total amount. | Number of rains. | Total amount. | Number of rains. | Total amount. |
| First half:              |                  |               |                  |               |                  |               |                  |               |
| Chattanooga.....         | 57               | 68.65         | 16               | 27.54         | 8                | 17.83         | 13               | 35.67         |
| Knoxville.....           | 44               | 51.01         | 26               | 45.59         | 13               | 29.44         | 4                | 11.04         |
| Total.....               | 101              | 119.66        | 42               | 73.13         | 21               | 47.27         | 17               | 46.71         |
| Mean.....                |                  |               |                  |               |                  |               |                  |               |
| Second half:             |                  |               |                  |               |                  |               |                  |               |
| Chattanooga.....         | 52               | 62.48         | 11               | 18.18         | 12               | 26.28         | 9                | 24.13         |
| Knoxville.....           | 48               | 55.87         | 21               | 35.47         | 10               | 22.19         | 10               | 27.48         |
| Total.....               | 100              | 118.35        | 32               | 53.65         | 22               | 48.47         | 19               | 51.61         |
| Mean.....                |                  |               |                  |               |                  |               |                  |               |

| December-May, 1883-1907. | 3 to 3.5 inches. |               | 3.5 to 4 inches. |               | 4 to 4.5 inches. |               | 4.5 + inches.    |               | Grand total. |
|--------------------------|------------------|---------------|------------------|---------------|------------------|---------------|------------------|---------------|--------------|
|                          | Number of rains. | Total amount. | Number of rains. | Total amount. | Number of rains. | Total amount. | Number of rains. | Total amount. |              |
| First half:              |                  |               |                  |               |                  |               |                  |               |              |
| Chattanooga.....         | 4                | 13.45         | 4                | 15.07         | 2                | 8.58          | 6                | 33.43         | 220.22       |
| Knoxville.....           | 4                | 12.70         | 1                | 3.78          | 2                | 8.79          | 4                | 22.04         | 184.39       |
| Total.....               | 8                | 26.15         | 5                | 18.85         | 4                | 17.37         | 10               | 55.47         | 404.61       |
| Mean.....                |                  |               |                  |               |                  |               |                  |               | 202.30       |
| Second half:             |                  |               |                  |               |                  |               |                  |               |              |
| Chattanooga.....         | 4                | 13.41         | 2                | 7.71          | 2                | 8.38          | 4                | 23.27         | 183.84       |
| Knoxville.....           | 5                | 16.17         | 2                | 7.46          |                  |               |                  |               | 164.64       |
| Total.....               | 9                | 29.58         | 4                | 15.17         | 2                | 8.38          | 4                | 23.27         | 348.48       |
| Mean.....                |                  |               |                  |               |                  |               |                  |               | 174.24       |

The data of the above table have been divided into two periods of twelve years each, with the following results:

*First period.*

|                                                 |     |
|-------------------------------------------------|-----|
| Total number of heavy rains at Chattanooga..... | 110 |
| Total number of heavy rains at Knoxville.....   | 100 |
| Total.....                                      | 210 |

Total amount of the above heavy rains as per table, 404.61 inches.

Dividing this total by two, to get the approximate average of the heavy rains for the watershed, we get 202.30 inches.

|                                                                         |     |
|-------------------------------------------------------------------------|-----|
| Total number of days with stages of 20 feet or more at Chattanooga..... | 166 |
|-------------------------------------------------------------------------|-----|

Dividing the amount of the heavy rains in the watershed by the number of days with a river stage of 20 feet or over, we get  $\frac{202.30}{166} = 1.220$  inches as the amount of rain-fall that probably produced one day of a stage of water in the river of 20 feet or more.



*Second period.*

|                                                 |     |
|-------------------------------------------------|-----|
| Total number of heavy rains at Chattanooga..... | 96  |
| Total number of heavy rains at Knoxville.....   | 96  |
| Total.....                                      | 192 |

Total amount of the above heavy rains, 348.48 inches.

Dividing this total as before, we get as an approximate average of the heavy rains in the watershed 174.24 inches.

|                                                                       |     |
|-----------------------------------------------------------------------|-----|
| Total number of days with stages of 20 feet or over in the river..... | 141 |
|-----------------------------------------------------------------------|-----|

Dividing as before, we get as the probable amount of rainfall in the second period required to produce a day of 20 feet or over in the river, 1.236 inches, as against 1.220 inches in the first period.

The difference between the line of reasoning employed in getting the above results and those given in Water-Supply Paper No. 234 is that the author of the latter attempts to differentiate between the stages produced by rains of varying intensity and to assign to such rains a given number of so-called "flood days," while in this paper the assertion is made that in the first period there were a given number of days with a stage of 20 feet and over in the river, and that during that time the heavy or flood-producing rains amounted to so much. Dividing, then, the total of the flood-producing rains by the corresponding number of days with a stage of 20 feet or over, the results given above are reached, viz, that for the first period it took 1.22 inches of rainfall to produce a day with a 20-foot stage in the river. These figures contradict the contention that an equal depth of rain in the last period as compared with the first produced more severe floods in the river. I only present them to show how easy it is to arrange data so as to prove both sides to a question. While this line of inquiry is open to less objection than that followed by Leighton, it does conform to the plan of the latter in so far as it uses the number of days that the river stood at or above 20 feet, instead of taking into consideration the actual height of the water. The most that can be said is that this form of inquiry shows no increase in flood intensity.

*Rainfall and run-off of the Ohio Basin.*—We now come to a different and more reliable form of investigating this question of the relation of precipitation to run-off.

We have no direct method of measuring the run-off, but we can reach a fair approximation to it by a comparison of the rainfall and river data for any given watershed. If, for example, the surface conditions over any considerable part of a watershed have been materially changed by deforestation or other means, and if, as claimed, such change operates to increase the run-off, then the flow of water in the streams after the change has been brought about should be greater for equal depth of precipitation. This method is a rough one, to be sure, but it appears to be the only one permitted by the records as they exist.

Cincinnati, Ohio, has been chosen as the point whose river observations are best adapted to our purpose, although some objection to that place lies in the constriction of the natural river channel caused by the encroachment on the banks of the stream by various artificial structures. The station at Pittsburg, Pa., is better situated for comparative purposes, but the low-water stages at that place of



late years have been vitiated by the construction of the Davis Island dam. The construction of dams at several places in other rivers has lowered the value of low river gauge readings for comparative purposes.

In the tables which follow I have given the actual mean monthly stage of the Ohio at Cincinnati for every month of the period 1871 to 1908. The average of these monthly means has been computed for the first period of nineteen years; these averages have been summed up for the twelve months of the year, and that sum has been divided by twelve in order to get the annual mean. The number so obtained, 17.3 feet, is therefore the average stage of the river for the entire nineteen years, as computed from all of the daily stages for that period. In like manner the average stage of the river for the second period of years has been computed and is given in the following table:

*Mean monthly and annual river stages in the Ohio River at Cincinnati, Ohio, for the period 1871-1908.*

[In feet and tenths.]

| Year.          | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Annual. |
|----------------|------|------|------|------|------|-------|-------|------|-------|------|------|------|---------|
| 1871.....      | 14.6 | 23.1 | 25.3 | 16.5 | 21.8 | 8.2   | 7.1   | 5.1  | 5.4   | 3.2  | 6.5  | 7.3  | .....   |
| 1872.....      | 14.0 | 14.1 | 13.3 | 25.8 | 11.8 | 10.9  | 11.9  | 8.4  | 5.1   | 4.2  | 10.0 | 10.5 | .....   |
| 1873.....      | 22.6 | 29.4 | 21.4 | 29.2 | 25.6 | 9.2   | 13.3  | 10.0 | 6.6   | 7.3  | 15.6 | 28.6 | .....   |
| 1874.....      | 29.7 | 27.9 | 25.7 | 31.6 | 20.7 | 7.8   | 6.1   | 9.0  | 4.2   | 5.4  | 4.6  | 13.4 | .....   |
| 1875.....      | 18.3 | 16.7 | 34.4 | 23.9 | 14.7 | 11.8  | 25.0  | 26.7 | 5.1   | 7.4  | 15.9 | 24.3 | .....   |
| 1876.....      | 31.4 | 33.9 | 25.6 | 25.4 | 18.2 | 10.1  | 11.8  | 10.6 | 16.8  | 10.7 | 11.7 | 12.1 | .....   |
| 1877.....      | 28.1 | 18.4 | 28.0 | 23.1 | 17.4 | 12.1  | 11.3  | 5.5  | 6.2   | 5.1  | 12.1 | 15.1 | .....   |
| 1878.....      | 20.0 | 24.2 | 24.2 | 14.5 | 22.0 | 12.5  | 9.0   | 10.6 | 13.7  | 6.0  | 14.8 | 29.1 | .....   |
| 1879.....      | 23.2 | 26.6 | 32.8 | 22.9 | 11.4 | 7.1   | 5.6   | 9.9  | 6.9   | 3.2  | 5.4  | 19.2 | .....   |
| 1880.....      | 29.2 | 28.3 | 35.2 | 24.6 | 15.8 | 14.0  | 9.4   | 8.4  | 7.0   | 4.6  | 10.4 | 18.1 | .....   |
| 1881.....      | 20.7 | 33.1 | 27.2 | 29.4 | 16.1 | 16.5  | 7.8   | 4.9  | 3.6   | 4.4  | 14.8 | 25.0 | .....   |
| 1882.....      | 42.0 | 44.0 | 34.2 | 18.2 | 30.6 | 26.5  | 16.9  | 13.7 | 13.9  | 9.0  | 8.7  | 12.7 | .....   |
| 1883.....      | 18.1 | 48.6 | 20.3 | 36.0 | 49.0 | 61.5  | 12.9  | 8.7  | 4.4   | 7.9  | 38.0 | 32.2 | .....   |
| 1884.....      | 24.5 | 54.4 | 36.5 | 24.5 | 17.5 | 11.3  | 8.5   | 6.5  | 3.6   | 3.9  | 4.4  | 12.2 | .....   |
| 1885.....      | 25.6 | 15.6 | 17.1 | 26.5 | 15.0 | 14.7  | 6.8   | 12.5 | 11.0  | 8.5  | 15.5 | 18.1 | .....   |
| 1886.....      | 24.7 | 26.0 | 20.6 | 37.4 | 22.0 | 15.5  | 13.8  | 10.0 | 5.4   | 5.2  | 12.2 | 19.4 | .....   |
| 1887.....      | 20.4 | 48.4 | 29.4 | 24.0 | 20.6 | 14.8  | 5.7   | 4.9  | 3.3   | 3.3  | 3.6  | 6.1  | .....   |
| 1888.....      | 20.2 | 20.1 | 23.0 | 23.8 | 13.8 | 10.4  | 14.6  | 12.1 | 16.4  | 17.9 | 27.4 | 16.2 | .....   |
| 1889.....      | 25.2 | 24.1 | 20.9 | 19.0 | 16.0 | 25.2  | 18.5  | 12.2 | 6.7   | 8.0  | 24.6 | 23.9 | .....   |
| 1890.....      | 33.0 | 37.9 | 46.0 | 31.7 | 32.5 | 19.8  | 10.8  | 9.7  | 20.8  | 21.2 | 24.2 | 17.3 | .....   |
| 1891.....      | 31.8 | 46.8 | 37.2 | 30.6 | 9.8  | 18.9  | 13.0  | 11.2 | 9.7   | 4.9  | 9.6  | 18.9 | .....   |
| 1892.....      | 23.8 | 24.5 | 25.4 | 31.5 | 25.2 | 23.1  | 11.6  | 7.7  | 5.7   | 4.3  | 6.4  | 11.1 | .....   |
| 1893.....      | 12.7 | 41.1 | 25.8 | 26.8 | 36.1 | 14.9  | 8.3   | 4.8  | 7.2   | 10.5 | 9.5  | 16.5 | .....   |
| 1894.....      | 17.3 | 27.2 | 22.6 | 19.1 | 16.9 | 12.3  | 5.6   | 4.3  | 4.8   | 4.6  | 6.6  | 12.0 | .....   |
| 1895.....      | 28.3 | 13.9 | 27.4 | 24.4 | 12.3 | 6.5   | 7.5   | 6.1  | 4.9   | 3.0  | 3.4  | 9.4  | .....   |
| 1896.....      | 14.1 | 23.6 | 22.5 | 26.1 | 12.3 | 11.7  | 22.1  | 20.1 | 6.7   | 14.8 | 13.8 | 19.7 | .....   |
| 1897.....      | 14.4 | 36.3 | 40.3 | 26.3 | 23.1 | 12.8  | 13.9  | 10.3 | 4.8   | 3.5  | 8.0  | 17.8 | .....   |
| 1898.....      | 35.3 | 25.0 | 31.3 | 27.1 | 23.7 | 11.7  | 8.6   | 20.2 | 7.7   | 10.1 | 17.1 | 18.7 | .....   |
| 1899.....      | 31.8 | 25.9 | 40.1 | 26.7 | 17.4 | 13.6  | 8.4   | 8.0  | 5.1   | 3.9  | 6.4  | 13.4 | .....   |
| 1900.....      | 18.7 | 24.5 | 28.9 | 17.8 | 11.2 | 10.8  | 9.5   | 7.9  | 5.0   | 4.3  | 10.3 | 19.2 | .....   |
| 1901.....      | 15.8 | 13.8 | 22.2 | 39.5 | 25.5 | 28.1  | 13.1  | 9.6  | 10.9  | 6.4  | 5.6  | 20.6 | .....   |
| 1902.....      | 19.9 | 19.2 | 37.2 | 26.7 | 13.6 | 11.0  | 19.4  | 9.9  | 4.4   | 7.6  | 6.3  | 26.9 | .....   |
| 1903.....      | 23.1 | 39.7 | 42.5 | 32.9 | 12.0 | 13.5  | 12.7  | 6.7  | 8.2   | 6.6  | 7.3  | 9.6  | .....   |
| 1904.....      | 19.4 | 20.3 | 34.6 | 26.6 | 20.1 | 16.2  | 13.5  | 6.3  | 5.0   | 3.8  | 4.2  | 4.6  | .....   |
| 1905.....      | 14.9 | 21.4 | 33.3 | 19.7 | 25.2 | 16.3  | 15.8  | 12.9 | 10.2  | 10.8 | 12.0 | 25.6 | .....   |
| 1906.....      | 26.8 | 13.9 | 36.3 | 30.3 | 14.3 | 12.5  | 10.1  | 14.4 | 10.1  | 13.3 | 15.8 | 23.3 | .....   |
| 1907.....      | 45.7 | 22.0 | 40.1 | 23.9 | 22.5 | 27.2  | 18.3  | 13.5 | 12.1  | 10.6 | 17.0 | 19.4 | .....   |
| 1908.....      | 22.0 | 32.2 | 41.9 | 35.8 | 30.8 | 12.9  | 10.0  | 8.6  | 4.4   | 3.6  | 4.8  | 5.2  | .....   |
| Mean:          |      |      |      |      |      |       |       |      |       |      |      |      |         |
| 1871-1889..... | 23.8 | 29.3 | 26.1 | 25.1 | 20.0 | 15.8  | 11.4  | 10.0 | 7.6   | 6.6  | 13.5 | 18.1 | 17.3    |
| 1890-1908..... | 23.6 | 26.8 | 32.9 | 27.6 | 20.2 | 15.5  | 12.2  | 10.1 | 7.8   | 7.8  | 9.9  | 16.3 | 17.6    |
| 1871-1908..... | 23.7 | 28.1 | 29.5 | 26.3 | 20.1 | 15.6  | 11.8  | 10.0 | 7.7   | 7.2  | 11.7 | 17.2 | 17.4    |

The average precipitation for the watershed has not been so easily obtained. Only in exceptional cases are continuous measurements of precipitation available for comparative studies. The government records in large cities are of necessity made from gauges whose imme-



climate environment has been changed repeatedly in the course of a long series of years, and it was for this reason that the rain-gauge records from Cincinnati and Pittsburg were ignored. The points selected—viz, North Lewisburg and Portsmouth, Ohio, and Confluence and Franklin, Pa.—are the best and practically the only long-period records available in this watershed. A better distribution throughout the watershed would have been preferred, but it is not possible to obtain it. The precipitation, like the river stages, has been computed in periods of nineteen years each. The tables follow:

*Annual precipitation in the Ohio watershed for the period 1871 to 1908, inclusive.*

[In inches and tenths.]

| Year.                  | North Lewisburg, Ohio. | Portsmouth, Ohio. | Confluence, Pa.   | Franklin, Pa.     | For the watershed. |
|------------------------|------------------------|-------------------|-------------------|-------------------|--------------------|
| 1871                   | 30.6                   | 30.7              | <sup>a</sup> 27.7 | 34.7              | .....              |
| 1872                   | 28.6                   | 31.1              | <sup>a</sup> 31.0 | 41.5              | .....              |
| 1873                   | 37.2                   | 46.2              | <sup>a</sup> 41.4 | 54.9              | .....              |
| 1874                   | 34.0                   | 38.3              | <sup>a</sup> 39.4 | 47.4              | .....              |
| 1875                   | 43.2                   | 45.7              | 39.1              | 45.8              | .....              |
| 1876                   | 42.0                   | 41.2              | 46.4              | 46.9              | .....              |
| 1877                   | 37.3                   | 35.0              | 45.0              | 43.5              | .....              |
| 1878                   | 44.0                   | 29.9              | 41.1              | 40.1              | .....              |
| 1879                   | 48.4                   | 35.6              | 38.8              | 37.7              | .....              |
| 1880                   | 46.4                   | 49.0              | 49.2              | 34.0              | .....              |
| 1881                   | 44.0                   | 40.8              | 41.4              | 39.1              | .....              |
| 1882                   | 45.8                   | 56.2              | 55.1              | 45.8              | .....              |
| 1883                   | 48.9                   | 48.5              | 49.8              | 41.3              | .....              |
| 1884                   | 34.3                   | 42.3              | 42.1              | 42.0              | .....              |
| 1885                   | 38.8                   | 37.3              | 39.3              | 44.6              | .....              |
| 1886                   | 40.6                   | 45.3              | 44.1              | 38.8              | .....              |
| 1887                   | 35.0                   | 40.7              | <sup>b</sup> 31.2 | 40.8              | .....              |
| 1888                   | 47.6                   | 48.3              | <sup>b</sup> 47.3 | 49.2              | .....              |
| 1889                   | 30.8                   | 39.3              | 40.0              | 43.8              | .....              |
| 1890                   | 45.2                   | 57.6              | 60.1              | 58.5              | .....              |
| 1891                   | 44.2                   | 42.8              | 57.5              | <sup>c</sup> 51.4 | .....              |
| 1892                   | 40.2                   | 44.1              | 38.4              | <sup>c</sup> 47.6 | .....              |
| 1893                   | 49.1                   | 37.9              | 43.4              | <sup>c</sup> 48.7 | .....              |
| 1894                   | 39.6                   | 36.2              | 42.1              | <sup>c</sup> 43.3 | .....              |
| 1895                   | 29.0                   | 31.2              | 35.1              | <sup>c</sup> 33.5 | .....              |
| 1896                   | 48.3                   | 39.9              | 50.2              | <sup>c</sup> 41.2 | .....              |
| 1897                   | 43.5                   | 49.1              | 45.8              | 39.6              | .....              |
| 1898                   | 52.2                   | 48.1              | 53.2              | 39.1              | .....              |
| 1899                   | 34.0                   | 42.9              | 48.9              | 32.8              | .....              |
| 1900                   | 32.5                   | 34.6              | 44.0              | 31.7              | .....              |
| 1901                   | 29.6                   | 39.7              | 41.2              | 42.2              | .....              |
| 1902                   | 36.6                   | 37.2              | 45.9              | 39.1              | .....              |
| 1903                   | 28.7                   | 37.3              | 38.3              | 45.6              | .....              |
| 1904                   | 35.4                   | 29.2              | 31.4              | 40.8              | .....              |
| 1905                   | <sup>d</sup> 35.1      | 43.3              | 51.1              | 45.1              | .....              |
| 1906                   | <sup>d</sup> 33.7      | 44.4              | 48.7              | <sup>c</sup> 40.2 | .....              |
| 1907                   | <sup>d</sup> 37.6      | 42.3              | 55.8              | <sup>c</sup> 42.3 | .....              |
| 1908                   | 30.1                   | 40.0              | 42.1              | <sup>c</sup> 41.1 | .....              |
| Mean:                  |                        |                   |                   |                   |                    |
| 1871-1889              | 39.8                   | 41.1              | 41.5              | 42.7              | 41.3               |
| 1890-1908              | 38.1                   | 40.9              | 46.0              | 42.3              | 41.8               |
| Mean for entire period | 39.0                   | 41.0              | 43.8              | 42.5              | 41.6               |

<sup>a</sup> Record of Pittsburg, Pa.

<sup>b</sup> Record of Lock No. 4, Pennsylvania.

<sup>c</sup> Record of Warren, Pa.

<sup>d</sup> Record of Columbus, Ohio.

<sup>e</sup> Record of Parkers, Pa.

### Summarizing the above, we have:

| Average stage of the Ohio River at Cincinnati, Ohio:                                      | Feet.   |
|-------------------------------------------------------------------------------------------|---------|
| 1871 to 1889                                                                              | 17.3    |
| 1890 to 1908                                                                              | 17.5    |
| Average precipitation in the Ohio watershed, as determined from the stations above named: | Inches. |
| 1871 to 1889                                                                              | 41.3    |
| 1890 to 1908                                                                              | 41.8    |



I consider that the results secured from the discussion of the precipitation and the gauge readings in the Ohio basin, as given in the foregoing tables, form one of the most important contributions made by this paper. Here we have avoided the using of indefinite and meaningless data, and have taken the longest period of time for which accurate records can be secured on a watershed that is suitable for this line of inquiry. We have not simply counted the number of days that the river stood above some arbitrarily selected stage without taking into consideration the exact height of the river. Neither have we divided the gauge readings by some arbitrarily selected portion of precipitation data. On the contrary, we have endeavored to profit by the errors of previous investigations, and to lay the foundation of an inquiry that would mean something when we reached the end of our computations. For this reason we have selected a typical station on the main stream that drains the Ohio Basin and have discussed rainfall data that are the most accurate of any in the region, having been subject to less errors due to varying environments. Any deductions made from an inquiry founded with less care, or from data of a less degree of accuracy, must bring results from which it would be unsafe to form definite conclusions.

Now let us see what is the result. The average stage of the river for the first nineteen years is 17.3 feet, and for the last nineteen years 17.5 feet, showing that there is practically no change in the run-off of the Ohio Basin between the first period and the last. When we examine the average precipitation over the watershed that is drained by this river we find that for the first nineteen years it was 41.3 inches, and for the last nineteen-year period it was 41.8 inches, a slight increase in precipitation for the latter period that agrees precisely with the slightly greater average flow of water. There is a perfect agreement here between the precipitation and the flow of the stream. I do not know what has been the area deforested in this valley during the thirty-eight years under discussion, but whatever it is it seems to be apparent that such altering of the relation of forest area to cultivated area has had no appreciable effect on the flow of the Ohio River. I am aware of the fact that by the studying of short periods of data on small tributary streams, and especially by the grouping of data dissimilar from what is employed in this discussion, all manner of results may be shown.

*I believe that the reader will acknowledge that I have shown in the several preceding paragraphs that the average discharge of the Ohio River, where I presume deforestation has been as great as in any other part of the country during recent time, has not changed for a period of thirty-eight years, except as caused by precipitation. It will now be interesting to know how the two periods compare with regard to extremely high water and extremely low water, and this will be discussed in the coming pages.*

*High water and low water on the rivers of the Ohio basin.*—I had Prof. H. C. Frankenfield, Chief of the River and Flood Division of the Weather Bureau, compile the data from one station on the Cumberland, three on the Tennessee, and five on the Ohio, and establish the average high water for the four wet months, January to April, and the average low water for the four dry months, July to October. He then



took the departure from the normal, both for the precipitation and for the height of the rivers, and found that *the average high water was no higher and the average low water was no lower for the last half of the period than for the first half*. The differences were so slight as to be inappreciable, but what changes occurred were in favor of the low water being slightly higher and the flood waters slightly less. There were variations in the periods and intensities of floods that bear a direct and proper relation to the precipitation. In making his report, Professor Frankenfield points to the fact that the low-water stages at Pittsburg, Pa., and Nashville, Tenn., are not fairly comparable with those of the other stations on account of permanent pool stages caused by dams operated during the low-water season for purposes of navigation. The first dam below Pittsburg was placed in operation in 1885, and that at Nashville in 1904. The effect of these dams is to furnish higher low-water stages than would result without them. The effect upon the normal low-water stage at Nashville was not marked, but at Pittsburg it was perceptible. However, in his conclusions he did not make allowance for the slightly higher low-water stages at Pittsburg on account of the dam, but when included with the other stages of the river this defect probably is not apparent.

According to our line of reasoning, which we believe to be fair and conservative, it is shown that the average discharge of the Ohio River is not greater as the result of deforestation during the last nineteen years than during the preceding like period, and that the average high water in the rivers of the entire basin, which includes the Tennessee, the Cumberland, and the Ohio, is not higher and the low water is not lower.

*Are real flood stages more numerous than formerly?*—The next line of inquiry will be for the purpose of determining whether or not there has been in recent time an increase in the number of days that these rivers were at or above the flood stage, and in making this inquiry *exact flood stages* will be used, not simply gauge readings less than flood. Again I called on Professor Frankenfield to prepare the necessary data. As the data was not complete with regard to flood stages for the first ten years of the period that we have been discussing, he took a period of ten years less in length, beginning with 1879, and as the result of his computations we have the following table



*Number of days in each year that the rivers were at or above the flood stage.*

[Flood stage given with name of station.]

|                          | Cumberland River, Nashville, Tenn. | Tennessee River.   |                |                     | Ohio River.    |                   |                 |                  |             | Total. |
|--------------------------|------------------------------------|--------------------|----------------|---------------------|----------------|-------------------|-----------------|------------------|-------------|--------|
|                          |                                    | Chattanooga, Tenn. | Florence, Ala. | Johnsonville, Tenn. | Pittsburg, Pa. | Cincinnati, Ohio. | Louisville, Ky. | Evansville, Ind. | Cairo, Ill. |        |
| Flood stage in feet..... | 40                                 | 33                 | 16             | 21                  | 22             | 50                | 28              | 35               | 45          |        |
| Year.                    |                                    |                    |                |                     |                |                   |                 |                  |             |        |
| 1879.....                | 3                                  | 3                  | 10             | <sup>a</sup> 19     |                |                   |                 | 4                |             |        |
| 1880.....                | 19                                 | 4                  | 19             | <sup>a</sup> 51     |                |                   | 4               | 31               |             |        |
| 1881.....                |                                    |                    | 4              | (b)                 | 3              | 2                 |                 | 11               |             |        |
| 1882.....                | 30                                 | 9                  | 44             | 80                  |                | 9                 | 8               | 63               |             | 6      |
| 1883.....                | 6                                  | 4                  | 15             | <sup>a</sup> 73     | 2              | 16                | 15              | <sup>a</sup> 34  |             | 21     |
| 1884.....                | 25                                 | 12                 | 42             | <sup>a</sup> 91     | 3              | 19                | 19              | 51               |             | 40     |
| 1885.....                |                                    |                    | 10             | 20                  | 1              |                   |                 | 5                |             |        |
| 1886.....                | 14                                 | 11                 | 17             | 31                  | 1              | 12                | 11              | 19               |             | 21     |
| 1887.....                | 11                                 |                    | 10             | 44                  |                | 13                | 11              | 53               |             | 32     |
| 1888.....                |                                    |                    | 13             | 27                  |                |                   |                 | 3                |             | 5      |
| 1889.....                |                                    |                    | 8              | 12                  |                |                   |                 |                  |             |        |
| 1890.....                | 14                                 | 5                  | 16             | 55                  | 2              | 14                | 17              | 65               |             | 39     |
| 1891.....                | 15                                 | 9                  | 35             | 63                  | 4              | 8                 | 6               | 67               |             | 13     |
| 1892.....                |                                    | 5                  | 18             | 40                  | 1              |                   |                 | 8                |             | 30     |
| 1893.....                | 3                                  | 1                  | 17             | 44                  | 2              | 10                | 2               | 28               |             | 18     |
| 1894.....                | 3                                  |                    | 2              | 14                  | 1              |                   |                 |                  |             |        |
| 1895.....                |                                    |                    | 4              | 15                  | 1              |                   |                 | 3                |             |        |
| 1896.....                | 6                                  | 4                  | 7              | 18                  |                |                   |                 | 6                |             |        |
| 1897.....                | 16                                 | 9                  | 29             | 48                  | 2              | 8                 | 7               | 36               |             | 48     |
| 1898.....                |                                    |                    |                | 20                  | 3              | 15                | 15              | 37               |             | 17     |
| 1899.....                | 2                                  | 13                 | 26             | 66                  | 1              | 9                 | 5               | 39               |             | 26     |
| 1900.....                |                                    |                    | 4              | 18                  | 1              |                   |                 |                  |             |        |
| 1901.....                |                                    | 1                  | 17             | 42                  | 3              | 9                 | 7               | 12               |             |        |
| 1902.....                | 12                                 | 6                  | 30             | 50                  | 3              | 4                 |                 | 26               |             |        |
| 1903.....                | 1                                  |                    | 31             | 58                  | 3              | 8                 | 1               | 45               |             | 25     |
| 1904.....                |                                    |                    | 3              | 9                   | 4              |                   |                 | 19               |             | 15     |
| 1905.....                |                                    |                    | 3              | 13                  | 5              |                   |                 | 4                |             |        |
| 1906.....                |                                    | 1                  |                | 22                  |                | 1                 |                 | 11               |             | 12     |
| 1907.....                |                                    |                    |                | 24                  | 4              | 22                | 22              | 46               |             | 23     |
| 1908.....                |                                    |                    | 3              | 18                  | 3              | 12                | 5               | 57               |             | 11     |
| Total, 1879-1893.....    | 140                                | 63                 | 278            | 650                 | 19             | 107               | 93              | 442              | 281         | 2,073  |
| Total, 1894-1908.....    | 40                                 | 34                 | 159            | 435                 | 34             | 88                | 62              | 341              | 177         | 1,370  |
| Grand total....          | 180                                | 97                 | 437            | 1,085               | 53             | 195               | 155             | 783              | 458         | 3,443  |

<sup>a</sup> Data incomplete.

<sup>b</sup> Data missing for this year.

|                                                      |       |
|------------------------------------------------------|-------|
| Total 1879-1893.....                                 | Days. |
| Total 1894-1908.....                                 | 2,073 |
|                                                      | 1,370 |
| Excess of first period over second period.....       | 703   |
| Average per year, 1879-1893.....                     | 138.2 |
| Average per year, 1894-1908.....                     | 91.3  |
| Excess per year first period over second period..... | 46.9  |

From the foregoing it will be seen that in the first fourteen years there were 2,073 days that the Cumberland River at Nashville; the Ohio at Pittsburg, Cincinnati, Louisville, Evansville, and Cairo; the Tennessee at Chattanooga, Florence, and Johnsonville, were at the flood stage—that is, they were bank full or overflowing. During the last fourteen years the number of such days is 1,370, an excess in the first fourteen years of 703 days, or an average of 46.9 days excess per year in the first period over the second.

Now, I would guard against unsafe conclusions from these results. The fact is that abnormally heavy precipitation for several years in



the forepart of the first fourteen-year period, especially that which caused the famous 1882 flood, places such a preponderance of flood days in the first period that it would be unfair to claim that there has been any such permanent decrease in flood intensity as is shown by this table. It is given for what it is worth, and further to emphasize the fact that conclusions on which fundamental theories or policies are based should not be founded upon short-period data. While I am strongly of the opinion that there is no permanent increase in the number of flood days for the rivers of the United States as a whole, between the last fifty years and the preceding fifty years, I should not rely upon such short-period data as is contained in this table to sustain my belief. But if these data of twenty-eight years, which shows such a marked decrease in flood intensity of the rivers of the Ohio Valley, and which are founded upon unquestionably accurate data, are not sufficient evidence for a scientific man to claim statistical proof of the decrease of floods, what shall one say of the statements made by Messrs. Hall and Maxwell, of the Forest Service, in volume 2, Senate Document No. 676, in a paper on "Surface conditions and stream flow," which begins at page 112, as follows:

THE TENDENCY IS TOWARD INCREASED FLOODS.

On the Potomac River, for which measurements are given for eighteen years, the number of floods during the first half of the period was 19; during the second half, 26; while the number of days of flood in the first half was 33, and in the second half, 57.

On the Monongahela River measurements are given for twenty-two years. During the first half of the period there were 30 floods; during the second half, 52. The number of days of flood during the first half of the period was 55; during the second half, 100.

On the Ohio River measurements are given for twenty-six years. During the first half of the period there were 46 floods; during the second half, 59. The number of days of flood during the first half was 143; during the second half, 188.

On the Cumberland River measurements were given for eighteen years. During the first half of the period there were 32 floods; during the second half, 43. The number of days of flood during the first half was 89; during the second half, 102.

On the Wateree River measurements have gone on for sixteen years. In the first half of the period the number of floods was 46; in the second half, 70. The number of days of flood in the first half of the period was 147; in the last half, 187.

On the Savannah River measurements have continued for eighteen years. During the first half of the period the number of floods was 47; during the second half, 58. The number of days of flood during the first period was 116; during the second half, 170.

On the Allegheny River measurements are given for thirty-four years. During the first half of the period there were 39 floods; during the second half, 53. The number of days of flood during the first half was 92; during the second half, 131.

On the Tennessee River measurements have been taken for thirty-four years. During the first half of the period there were 32 floods; during the second half, 33. The number of days of flood during the first half was 173; during the second half (in this case there was a falling-off), 137.

The conclusions arrived at by the authors are, in my judgment, faulty, because:

First. The shortness of the period of observations at the majority of the stations discussed.

Second. The arbitrary assumption as flood stages of certain heights of water much below that necessary to cause a flood.

As to the period of observations: Those of us who are accustomed to the computation of normals or mean values have always realized how little value they possess unless obtained from data covering a long period of years. This is true of temperature normals, which vary but little from year to year. How much more must it be true of precipitation and river-stage data, with their wide extremes and



irregular fluctuations? As a matter of fact any average of river conditions, or any mean annual precipitation determined from ten or fifteen years' observations, would be of little or no value in a discussion of this character, and when two of these short-period normals are compared with each other the actual errors would probably be multiplied.

Second, opinions may differ, of course, as to what constitutes a flood, but the Weather Bureau (and engineers generally) have uniformly defined a river to be in flood when it reached a stage above which damage would be caused, practically the bank-full stage. This being so, it would appear reasonable and proper that this definition of the term should be accepted and data discussed accordingly. If the flood stage at a given point is 18 feet, an assumption of a lower or a higher figure for purposes of investigating the frequency of floods must necessarily be misleading.

I will now take up the rivers in the order named in the quotation and give the net result of Professor Frankenfield's inquiry as to the number of *real* floods:

*Potomac*.—On the Potomac River the number of floods has not increased, but there were more days of a 12-foot stage in the last period than in the first. The explanation of this increase is found in the precipitation.

*Monongahela*.—On the Monongahela River, using data for Lock No. 4, Pennsylvania, 40 miles above Pittsburg, there were two more floods in the second period as compared with the first, the figures being 13 and 11, respectively. Two of the days of flood occurred in March, 1907, as a result of abnormal weather conditions over the watershed.

*Ohio at Wheeling*.—There was an increase in the number of floods at Wheeling, but said increase is not shown farther down the river than Parkersburg. It (the increase) disappeared below the mouth of the Great Kanawha, as indicated by the Cincinnati records. The reason ascribed for this increase in flood frequency is an increase in short-period heavy rains. The same conditions appear to have obtained in the Allegheny at Freeport.

*Cumberland*.—There has been no increase in flood conditions in the Cumberland.

*Wateree*.—There was a marked increase in the number of flood days on this river during the second period. On the other hand, the precipitation in the watershed shows a like marked increase.

*Savannah*.—The record for the Savannah River at Augusta shows a marked decrease in the second period as compared with the first.

*Allegheny at Freeport*.—See Wheeling.

*Tennessee*.—See detailed discussion on this river in another part of this paper.

#### CONCLUSIONS.

(1) Any marked climatic changes that may have taken place are of wide extent and not local, are appreciable only when measured in geologic periods, and evidence is strong that the cutting away of the forests has had nothing to do with the creating or the augmenting of droughts in any part of the world.

(2) Precipitation controls forestation, but forestation has little or no effect upon precipitation.



(3) Any local modification of temperature and humidity caused by the presence or absence of forest covering, the buildings of villages and cities, etc., could not extend upward more than a few hundred feet, and in this stratum of air saturation rarely occurs, even during rainfall, whereas precipitation is the result of conditions that exist at such altitudes as not to be controlled or affected by the small thermal irregularities of the surface air.

(4) During the period of accurate observations, the amount of precipitation has not increased or decreased to an extent worthy of consideration.

(5) Floods are caused by excessive precipitation, and the source of the precipitation over the central and eastern portions of the United States is the vapor borne by the warm southerly winds from the Gulf of Mexico and the adjacent ocean into the interior of the country, but little from the Pacific Ocean crossing the Rocky Mountains.

(6) Compared with the total area of a given watershed, that of the headwaters is usually small and, except locally in mountain streams, their run-off would not be sufficient to cause floods, even if deforestation allowed a greater and quicker run-off. Granting for the sake of argument that deforestation might be responsible for general floods over a watershed, it would be necessary, in order to prevent them, to reforest the lower levels with their vastly greater areas, an impossibility unless valuable agricultural lands are to be abandoned as food-producing areas.

(7) The run-off of our rivers is not materially affected by any other factor than the precipitation.

(8) The high waters are not higher, and the low waters are not lower than formerly. In fact, there appears to be a tendency in late years toward a slightly better low-water flow in summer.

(9) Floods are not of greater frequency and longer duration than formerly.









44



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EROSION-CONTROL  
SHORE LINES

American Society of Military Engineers  
Cleveland Chapter

SHORE EROSION, ITS CAUSE AND ITS CONTROL

September 26, 1947 - Lt. Col. George B. Sowers Corps of

Engineers O.R.C. Director Department of

Public Works - State of Ohio

1 - Shore erosion can be controlled and stopped. Unlike cancer which it strikingly resembles, given adequate money the cure can be effected. The cure, unfortunately, is very costly. Half-way measures, like quack doctoring in cancer cure, may appear to control for a time or may only move the erosion to another spot. Sometimes the "quack doctoring" also hastens the ravages of the cancer. Mayor Burke of Cleveland told us at a recent Chamber of Commerce meeting how the City had squandered \$150,000 upon a patented type of anti-shore erosion structure which not only had been a total failure but had increased the erosion at that location. Not all the "sure cures" have been sold to the public agencies. Throughout my recent inspection of the shore I heard the sad stories of cottage owners who had invested all they had in small shore protection structures only, this year, to see their property being washed away.

2 - Governor Herbert is very familiar with the devastation taking place along the Ohio shore of Lake Erie. He is deeply concerned over the destruction of the properties and has asked me to cooperate with all agencies, in so far as the State can do so, in combating erosion. The very small amount of money available limits the State's help for privately owned shore property to that of advice and planning. A small part of the much needed millions of dollars has been appropriated for engineering work and the protection of publicly owned shore property.

3 - Shore erosion problems are an old story to me. Thirty years ago I saw the shore of East 140th Street falling into the Lake. I designed and built the big stone breakwater which protects the City property at the East 140th Street Sewage Treatment Works. I watched the sand pile up on the shore west of this breakwater while the beaches east of the breakwater disappeared and the waves cut away the beautiful grounds of the shore. Since all the people have benefited through the building of the Easterly Sewage Treatment Works I have felt that the City had a moral obligation to help in protecting the shore and restoring the beaches east of the sewage treatment plant breakwater. The destruction taking place there this year is a sad sight.

4 - A few weeks ago I traveled along the entire shore of Lake Erie within Ohio with the Beach Erosion Board and District Engineers of the Corps. It was a most interesting and informative three days trip. The many informal discussions with the best shore erosion experts in the world was a real education. It was a privilege to stand by the side of those experts as we looked along the Lake at scenes of destruction comparable to those which I saw in the war and hear what they thought might cure or control the erosion.







List of badly damaged areas:

Reno Beach - Formerly a flooded marsh. Now protected by a dike from behind which the drainage is pumped. The dike has been breached and should have further protecting works built.

Cedar Point - The sand beach washed away and the road had been destroyed. A parallel stone fill had accumulated four feet of sand in June. When I saw it the sand was again eroded away.

North Palm Beach - Low clay cliff. Various types of bulkhead and short groins have been built by private owners in an attempt to stop bank erosion. The bank continues to wash away and big trees are falling into the water.

Ceylon Beach - In 1930 it had 75 feet width of beach while the paved highway was 50 feet shoreward of the top of the cliff. Today the sand is gone and 1½ miles of the highway destroyed.

Huntington Park - Cleveland Metropolitan Park Board. The erosion of the clay bank was stopped and a fine beach formed through the building of stone groins. High water and winds have washed much of the sand beach away and the cliff is endangered. Mr. Stinchcomb has recently submitted plans for increasing the size and extent of the stone groins at a cost of probably \$100,000.

Perkins Beach - A high shale cliff. There was a wide area of park twenty-five years ago. Today the park and half the paved street is gone. Woods patented permeable groin failed to function. \$150,000 squandered.

Shore Acres-Villa Beach - Cliff east of East 140th Street Sewage Treatment Works breakwater.

Perry Township Park - A local park. Many big trees have fallen into the Lake.

Conneaut Township Park - 100 foot high clay cliff going into the Lake.

These are some of the erosion problems confronting us in 1947. They are not new.

5 - Erosion has been the cancer eating away the Lake Shore for 20,000 years. The waters of Lake Erie have been attacking and moving back the cliffs ever since the great ice mass of the glacial period melted from the lake bed.

The shore of the Lake is made up largely of clay banks with a few stretches of shale cliff. Some of the clays are glacial till and others are lacustrine deposits in the glacial lake. The amount of sand and gravel in the clay at a few locations is as high as 15% but for the greater portion is only a few percent. These clays were laid down during the 250,000 years of the glacial period. The sand and gravel beds of Lake Erie were almost entirely formed during the last stages of the glacial period in the water flowing under the ice and along its margin. They are the result of the grinding of the glacial mill.

These sand grindings were washed and pushed along the Lake bed under the ice to be finally deposited in the west end of the Lake where they are found today by the dredging and sand sucker boats.

Another somewhat similar deposit was laid down across the Lake between Presque Isle opposite Erie, Pennsylvania and Long Point on the opposite Canadian shore.



List of badly damaged areas:

Beach Point - Formerly a flooded marsh. Now protected by a dike from Lake Michigan which the dike has been breached and should have further protection works built.

Beach Point - The sand beach washed away and the road had been destroyed. A parallel stone fill had accumulated four feet of sand in June. When I saw it the sand was again eroded away.

North Palm Beach - Low clay cliffs. Various types of bushes and short grass have been built by private owners in an attempt to stop beach erosion. The bank continues to wash away and big trees are falling into the water.

Caylor Beach - In 1930 it had 75 feet of beach while the paved highway was 50 feet short of the top of the cliff. Today the sand is gone and 15 miles of the highway destroyed.

Huntington Park - Cleveland, Mississippi Park Road. The erosion of the clay bank was stopped and a line beach formed through the building of stone groins. High water and winds have washed much of the sand beach away and the cliff is endangered. Mr. Belcher has recently submitted plans for increasing the size and extent of the stone groins at a cost of probably \$100,000.

Fortune Beach - A high white cliff. There was a wide area of park twenty-five years ago. Today the park and all the paved street is gone. Woods retained permeable groins failed to function. \$100,000 estimated.

Shore Acres-Villa Beach - Cliff road at East 14th Street Garage fronting North River.

Barry Township Park - A local park. Many big trees have fallen into the lake.

Greenland Township Park - 100 foot high cliff falling into the lake.

These are some of the erosion problems confronting us in 1947. They are not.

more.

3 - Kingston has been the center of erosion along the lake shore for 20,000 years. The waters of Lake Erie have been retreating and giving back the cliffs ever since that great ice mass of the glacial period melted from the lake bed.

The shore of the lake is made up largely of clay banks with low vegetation of shrub cliffs. Some of the clay and glacial till and others are limestone deposits in the glacial lake. The amount of sand and gravel on the shore is a few feet high as high as 150 feet for the greater portion is only a few feet high. These clay groins fell down during the 20,000 years of the glacial period. The sand and gravel beds of Lake Erie were almost entirely formed during the last stages of the glacial period in the water flowing under the ice and along its margin. They are the result of the retreating of the glacial till.

These sand groins were washed and washed along the lake bed under the ice and the clay deposited in the water at the lake shore they are found today by the dredging and sand-pumping boats.

Another somewhat similar deposit was laid down across the lake between Kingston and Point Pelee and Long Point on the opposite Canadian shore.



West of this line the Lake is very shallow, Max. 72 feet, while east of this line the lake is 130 feet deeper. Perhaps when the ice lobe was in only this deep eastern end of the lake the up-rush of the water formed the sand bar across the middle of the lake.

These sand deposits of the lake bottom may be a counterpart of the great sand and gravel bars of Ohio and New York which are the source of our bank sands.

To produce an ordinary narrow sand beach today requires the eroding away and washing out of the sand from 250 to 1,000 cubic yards of clay. The shore must erode 500 to 1,000 feet in depth to produce enough sand for a narrow width of bathing beach.

The Cuyahoga River has not added one cubic foot of sand to the beaches during the last 100 years. The sand washed from the land is deposited in the ship channel and hauled out into deep water each year by dredges. This same situation applies to nearly every river and creek flowing into the lakes for they are all boat harbors.

The mineral wealth of Ohio as represented by the Lake sand beds has been very largely dredged out to build bridges, factories, roads and homes. It is not being replenished except slowly and at the expense of the shore owners.

The remaining sand in the beds of lake Erie must be held in reserve to be used in the rebuilding and new building of bathing beaches to be enjoyed by all the people of Ohio.

New York State no longer permits the removal of sand from Lake Erie and Ontario.

The State of Pennsylvania has forbidden the dredging of sand from two of the three sand beds in Lake Erie within that State because of the very serious and damaging erosion which has taken place along Presque Isle, Lake Erie's greatest sand bar.

The State of Ohio has not issued sand dredging permits for 1947. They were prepared for issuing and on my desk when I took over the job of the Department of Public Works six weeks ago. I wanted to check up on the situation and have held up the issuing of the permits.

The absence of permits from the Department of Public Works has not interfered with the dredging and sale of the lake sand. Permits for the operation of the sand dredges based solely upon the ships and their operations not interfering with navigation, were secured early in the year from the United States Government. Such United States permits clearly state that they do not carry any right for the removal of the sand owned by the State. The sand dredgers in past years have agreed to pay the State 3 and 5 cents per cubic yard for such sand as they removed and they appear to be paying some amounts into the State Treasury this year for sand. I have an investigation under way of the sand and gravel dredging operations.

During the years 1942-43 the sand dredging contracts were generally on a lump sum basis although the price of 5 cents per cubic yard apparently had some use. The amount of sand removed from the Lake as reported by the Corps of Engineers indicates that the sand dredging operators paid the State only about 2 cents per cubic yard for the actual sand removed.

The sand dredging companies, under their State permits during the years 1944-45-46, reported to the Department of Public Works that they removed from Lake Erie and delivered at the Ohio ports within the Buffalo District of the Corps of Engineers (Sandusky to Conneaut) 595,420 cubic yards of sand for which they paid 5 cents per



East of this line the lake is very shallow, Max. 12 feet, while west of this line the lake is 150 feet deep. Perhaps when the lake was in only this deep eastern end of the lake the up-rush of the water forced the sand bar across the middle of the lake.

These sand deposits of the lake bottom may be a counterpart of the great sand and gravel bars of Ohio and New York which are the source of our beach sands.

To produce an ordinary narrow sand beach today requires the working away and washing out of the sand from 100 to 1,000 cubic yards of clay. The shore must erode 500 to 1,000 feet in depth to produce enough sand for a narrow width of bathing beach.

The Cuyahoga River has not added one cubic foot of sand to the beaches during the last 100 years. The sand washed from the land is deposited in the lake channel and hauled out into deep water each year by dredges. This same attention applies to nearly every river and creek flowing into the lakes for they are all lost forever.

The natural wealth of Ohio as represented by the lake sand has been very largely depleted out to public health, recreation, roads and homes. It is not being replenished enough quickly and at the expense of the future generations.

The remaining sand in the beds of Lake Erie must be held in reserve for use in the rebuilding and new building of bathing beaches as is enjoyed by all the people of Ohio.

New York State no longer permits the removal of sand from Lake Erie and Ontario. The State of Pennsylvania has forbidden the dredging of sand from the bottom of the lake since 1910. These sand beds in Lake Erie within that State because of the very serious and damaging erosion which has taken place along the shore line, Lake Erie's greatest sand bar.

The State of Ohio has not issued any dredging permits for 1917. They were prepared for issuing and on my desk when I took over the job of the Department of Public Works six weeks ago. I wanted to check up on the situation and have held up the issuing of the permits.

The absence of permits from the Department of Public Works has not interfered with the dredging and sale of the lake sand. Permits for the operation of the sand dredges based solely upon the title and their operations not interfering with navigation, were issued early in the year from the United States Government. Such United States permits clearly state that they do not carry any right for the removal of the sand owned by the State. The sand dredgers in Pennsylvania have agreed to pay the State 2 and 5 cents per cubic yard for each sand as they removed and they appear to be paying some amounts into the State Treasury this year for sand. I have an investigation under way of the sand and gravel dredging operations.

During the years 1913-14 the sand dredging contracts were generally on a lump sum basis although the price of 1 cent per cubic yard was generally bid and used. The amount of sand removed from the lake as reported by the Corps of Engineers indicates that the sand dredging operators paid the State only about 1 cent per cubic yard for the actual sand removed.

The sand dredging companies, under their State permits during the years 1913-14-15, reported to the Department of Public Works that they removed from Lake Erie and delivered at the Erie ports within the State's limits of the Corps of Engineers (Secretary to Lieutenant) 507,430 cubic yards of sand for which they paid 1 cent per



cubic yard up to 25,000 cubic yards and 3 cents for all over that quantity.

The Annual Report of the District Engineer at Buffalo shows that 1,084,000 cubic yards of sand were delivered at the same ports (Sandusky to Conneaut). There were 488,580 cubic yards of sand delivered but not reported to the State or paid for. At the 5 cent price this would have added \$24,429.00 to the State funds. During 1944 only 44% of the sand appears to have been reported and paid for. In 1945 it was 51% and in 1946 only 64% of the sand removed from the lake was reported and paid for within the Buffalo District of the Corps of Engineers.

The above figures and comparisons do not include the Detroit District harbors of which Toledo is the largest port. Much of the sand brought into Toledo harbor comes from Michigan waters and the Maumee River, making it difficult to prepare comparative figures except after a detailed audit.

The trip reports of the ship masters are being checked to determine how much the sand dredging companies have failed to report to the State and pay for. It looks very much as though the sand dredging companies were keeping two sets of books: one which they report to the State and base their payment upon; the other contains the records which are reported to the Corps of Engineers.

Watch the daily papers for quick denials of any error in the reporting but figures of the Corps of Engineers cannot be disputed.

I am told by building supply companies that sand has been selling on the dock at \$2.00 to \$2.50 per cubic yard. The State receives 5 cents per cubic yard for the first 25,000 cubic yards and 3 cents for all above that amount under the previous permits. There must be a nice profit in every ship load which is not shared with the people of Ohio who are the owners of the sand mineral resource. 20-25 cents would be a more reasonable price.

The Court of Common Pleas of Cuyahoga County has decided and the Supreme Court has sustained the decision, that the State holds title to the subsquence lands of navigable waters as trustees for the protection of the public rights therein. The Court held:

"3. The title of the land under the waters of Lake Erie within the limits of the State of Ohio, is in the State as trustees for the benefit of the people, for the public uses to which it may be adapted."

"6. The ownership of the waters of Lake Erie and of the land under them within the State is a matter of public concern. The trust with which they are held is governmental, and the State, as trustee for the people, cannot by acquiescence or otherwise, abandon the trust property or permit a diversion of it to private uses different from the object for which the trust was created. The littoral owner is charged with knowledge that nothing can be done by him that will destroy the rights of the public in the trust estate."

The General Assembly of Ohio has declared:

"Section 3699a, General Code - It is hereby declared that the waters of Lake Erie within the boundaries of the state, together with the soil beneath and their contents, do now and have always, since the organization of the State of Ohio, belonged to the State of Ohio as proprietor in trust for the people of the State of Ohio."



cubic yard up to 25,000 cubic yards and 5 cents for all over that quantity.

The Annual Report of the District Engineer at Buffalo shows that 1,000,000 cubic yards of sand were delivered at the same point (Sandusky to Commerce). There were 450,000 cubic yards of sand delivered but not reported to the State of Ohio for. At the 5 cent price this would have added \$22,500.00 to the State funds. Having paid only 44% of the sand required to have been reported and paid for. In 1905 it was 52% and in 1906 only 62% of the sand removed from the lake was reported and paid for within the Buffalo District of the Corps of Engineers.

The above figures and comparisons do not include the District Engineer's report of which Toledo is the largest part. Much of the sand brought into Toledo comes from Michigan waters and the Indiana River, making it difficult to properly comparative figures except after a detailed audit.

The trip reports of the ship masters are being changed to 5 minutes per hour the sand dredging companies have failed to report to the State and pay for. It looks very much as though the sand dredging companies were keeping two sets of books: one which they report to the State and have their payment upon; the other contains the records which are reported to the Corps of Engineers.

Watch the daily papers for dates certain of any error in the foregoing but figures of the Corps of Engineers cannot be disputed.

I am told by building supply companies that sand has been selling on the lake at \$1.00 to \$1.50 per cubic yard. The State receives 5 cents per cubic yard for the 1,000,000 cubic yards and 5 cents for all above that amount under the present permit. There must be a nice profit in every cubic yard which is not added with the people of Ohio who are the owners of the sand mineral resource. 250,000 cents would be a more reasonable price.

The Court of Common Pleas of Cuyahoga County has decided and the Supreme Court has sustained the decision, that the State holds title to the submerged lands of navigable waters as trustees for the protection of the public rights therein. The Court said:

"3. The title of the land under the waters of Lake Erie within the limits of the State of Ohio, is in the State as trustee for the benefit of the people, for the public uses to which it may be adapted."

"4. The ownership of the waters of Lake Erie and of the land under them within the State is a matter of public concern. The laws which relate thereto are held as governmental, and the State, as trustee for the people, cannot by incorporation or otherwise, transfer the trust property or permit a diversion of it to private use different from the object for which the trust was created. The first owner is charged with knowledge that nothing can be done by him that will transfer the rights of the public in the trust estate."

The General Assembly of Ohio has complied:

"Section 3000, General Code - It is hereby declared that the waters of Lake Erie within the boundaries of the State, together with the lands beneath and their contents, do not and have always, since the establishment of the State of Ohio, belonged to the State of Ohio as property in trust for the people of the State of Ohio."



The sand on the bed of Lake Erie clearly is the property of the people of Ohio held in trust by the State.

The General Assembly has given the Department of Public Works permission to sell the people's sand in Lake Erie under certain conditions and to use the money derived therefrom in combating the erosion of the shore. Through the use of this money the studies of the shore erosion problem have been carried on for the past several years. Now the General Assembly has made a special appropriation for this work.

The amount of money derived from the sale of the sand on one mile, 5,280 feet, of sand beach is about \$10,000 or enough to protect from erosion only 70 feet of shore after the sand beach has been removed and sold for construction purposes.

6 - Much of the shore erosion is occurring where the sand beach at the foot of the cliff has washed away. High lake levels flood the sand beaches and allow the waves to attack the toe of the cliff. The sand of the beach washes out into deep water and along the shore.

The continual hauling away, for commercial purposes, of the sand on a low water beach will soon deplete all of the beach along the shore for a long distance. The building of breakwaters, harbor entrance walls, jetties and groins too frequently are the cause of the disappearance of sand beaches along the shore.

7 - Beach sand within reach of the water is continually in motion. The sand grains are continually marching along the shore.

The sand beaches east of Lorain are all moving slowly in an easterly direction. The beaches west of Lorain are moving westerly.

This continual march of the sand grains is the work of the normal lake currents along the shore coupled with currents set up by the wind.

When the march of the sand grains is stopped by a breakwater or groin built out into deep water the sand piles up against the breakwater or groin and forms such fine beaches as those at East 140th Street, Fairport Harbor or Euclid Beach Park.

The column of sand beyond the barrier continues to march along and soon the shore is denuded. The beach starves to a shadow. The waves have full access to the shore. Erosion is rampant. The eroding of the cliff produces sand for the beaches down current.

8 - The flooding of the shore beaches by the high level of the water in the lake this year is a fairly regular occurrence.

The present high level cycle started in 1943. It should soon begin to lower. The last previous high cycle was 1929-30. There was another 1916-19. The 1943-47 cycle appears to resemble the 1883-87 cycle.

The lake level has been much lower. It has also been higher. Highest 574.3. Lowest 569.5. Monthly mean. 5 ft. range. High 1947 monthly average about 574.5. The high water in the west end of the lake has been aggravated by an unusual amount of N. E. winds which push the water from Buffalo to Toledo.

The cycles of high and low water, of course, follow the rain and snow fall cycles. The Lake Survey Office has been unable to attribute the cycles in lake levels to any such distant phenomena as sun spots.



The sand on the bed of Lake Erie clearly is the property of the people of Ohio and is held by the State.

The General Assembly has given the Department of Public Works permission to sell the people's sand in Lake Erie under certain conditions and to use the money derived therefrom in combating the erosion of the shore. Through the use of this money the erosion of the shore problem has been solved for the past several years. Now the General Assembly has made a special appropriation for this work.

The amount of money derived from the sale of the sand on one mile, 2,180 feet, of sand beach is about \$10,000 or enough to protect from erosion only 75 feet of shore after the sand beach has been removed and sold for construction purposes.

6 - Much of the shore erosion is occurring where the sand beach at the foot of the cliff has washed away. High lake levels flood the sand beaches and allow the waves to attack the toe of the cliff. The sand of the beach washes out into deep water and along the shore.

The continual pulling away, for commercial purposes, of the sand on a low water beach will soon deplete all of the beach along the shore for a long distance. The building of breakwaters, harbor entrance walls, jetties and groins too frequently are the cause of the disappearance of sand beaches along the shore.

7 - Beach sand within reach of the water is continually in motion. The sand grains are continually moving along the shore.

The sand beaches east of Cleveland are moving westerly. The sand beaches west of Detroit are moving easterly. This is an easterly direction.

This continual march of the sand grains is the work of the natural lake currents along the shore coupled with currents set up by the wind.

When the march of the sand grains is stopped by a breakwater or groin built out into deep water the sand piles up against the breakwater or groin and forms what are known as sand bars at East 140th Street, Fairport Harbor or Euclid Beach Park.

The column of sand beyond the barrier continues to march along and soon the shore is denuded. The beach erodes to a shadow. The waves have full access to the shore. Erosion is rampant. The eroding of the cliff produces sand for the beaches down current.

8 - The flooding of the shore beaches by the high level of the water in the lake this year is a fairly regular occurrence.

The present high level cycle started in 1943. It should soon begin to fall. The last previous high cycle was 1929-30. There was another 1910-12. The 1903-05 cycle appears to resemble the 1929-30 cycle.

The lake level has been much lower. It has also been higher. Highest 575.3, lowest 569.0. Monthly mean 5 1/2 ft. range. High 1947 monthly average about 574.5. The high water in the west end of the lake has been aggravated by an unusual amount of N. E. winds which push the water from Toledo to Toledo.

The cycles of high and low water, of course, follow the rain and snow fall cycles. The Lake Survey Office has been unable to attribute the cycles in lake levels to any such distant phenomena as sun spots.



Monthly average lake levels may fluctuate 5 feet through a 50-year period. The last period of low levels was 5 feet below the 1947 high level and occurred 1935. There have been times when the lake level at Buffalo was 12 or 13 feet lower than the level at Toledo, due to winds.

The Corps of Engineers has made extensive studies of structures which might be built to regulate the level of Lake Erie. It is possible to regulate the lake level. Many factors must be considered including the international complications in the development of electric power. One estimate of cost was \$14,000,000 for which it would be possible to reduce the fluctuation in level by about six inches. Too costly and too complicated.

9 - Structures to stop shore erosion are possible from an engineering standpoint but they are expensive. Some years ago while I was Chairman of the Port Commission I inspected such structures along the west shore of Lake Michigan where I saw a great pile of granite block laid parallel with the shore. It stopped the erosion of that estate's shore but it presented far from a pretty picture. It must have cost \$150 per foot at that time and would cost \$300 now. I also inspected the Wood's patented groin and recommended against its use in Cleveland.

A recent estimate of cost by the Corps of Engineers for a quarry run stone fill along the shore near Huron figured over \$150 per foot of shore.

The high piling of quarry run stone along an eroding shore will stop the erosion but there will be no sand beach and the shore is of little recreational use.

Groins at right angles to the shore extending out from the shore a distance approximately equal to  $2/3$  of the distance between groins has proven effective in many cases. Such groins may be of stone, concrete, steel sheet piling and timber. They can only be effective where there is sand drifting along the shore. Tight rather than permeable groins seem more effective where there is only a small amount of sand.

Groins are economical and effective only where there is a considerable length of shore so protected. One or two groins may result in increasing the erosion damage on adjacent properties.

The cost of groin construction, of a size which will be effective, may be the same or greater than the cost for a high pile of quarry run stone along the shore but in addition you may secure a bathing beach.

When there is no sand marching along the shore the beach can only be secured after building the groins and through piling 25 to 40 cubic yards of sand per foot of shore between the groins. Such a barren shore must have annual feedings of sand for several years until nature has re-established a sandy shore. The building of a beach on a barren shore may cost another \$150 per foot of shore for the sand.

Every mile of beach that must be built will require 250,000 cubic yards of sand. The actual amount of sand removed from Lake Erie in 1946 would build only about  $1\frac{1}{2}$  miles of new beach. Just enough for one park.

10 - The sand remaining on the bed of Lake Erie must last us until the next glacial period, probably 250,000 years. There will be no new sand made when we stop all the shore erosion.

That should be a sufficient reason for discontinuing the dredging of sand for



Monthly average lake levels may fluctuate 5 feet through a 30-year period. The last period of low levels was 5 feet below the 1917 high level and occurred in 1915. There have been times when the lake level at Duluth was 12 or 13 feet lower than the level at Toledo, due to winds.

The Corps of Engineers has made extensive studies of structures which might be built to regulate the level of Lake Erie. It is possible to regulate the lake level by means of a dam or a series of locks. The latter method is the more desirable in the development of electric power. The estimate of cost was \$14,000,000 for which it would be possible to reduce the fluctuation in level by about six inches. Too costly and too complicated.

9 - Structures to stop shore erosion are possible from an engineering standpoint but they are expensive. Some years ago while I was Chairman of the Port Commission I inspected such structures along the west shore of Lake Michigan where I saw a great pile of gravel and rock laid parallel with the shore. It stopped the erosion of that estate's shore but it presented for them a great problem. It cost \$100 per foot at that time and would cost \$150 now. I also inspected the local's patented grain and recommended against its use in Cleveland.

A recent estimate of cost by the Corps of Engineers for a quarry run stone fill along the shore near Huron figured over \$100 per foot of shore.

The high filling of quarry run stone along an eroding shore will stop the erosion but there will be no sand beach and the shore is of little recreational use.

Beaches at right angles to the shore extending out from the shore a distance of 100 to 200 feet are desirable. Such beaches may be of stone, concrete, gravel, shell, filling and timber. They can only be effective where there is sand drifting along the shore. Timber rather than permeable grain is more effective where there is only a small amount of sand.

Beaches are occasional and effective only where there is a considerable length of shore so protected. One or two groins may result in increasing the erosion damage on adjacent properties.

The cost of groin construction, of a size which will be effective, may be 50 cents or greater than the cost for a high pile of quarry run stone along the shore but in addition you may secure a bathing beach.

When there is no sand washing along the shore the beach can only be restored after building the groins and through filling 12 to 15 cubic yards of sand per foot of shore between the groins. Such a barren shore must have annual loading of sand for several years until nature has re-established a sandy beach. The building of a beach on a barren shore may cost another \$100 per foot of shore for the sand.

Every mile of beach that was to be built would require 1,000,000 cubic yards of sand. The actual amount of sand removed from Lake Erie in 1915 would build only about 1/10 mile of new beach. That beach for one year.

10 - The sand remaining on the bottom of Lake Erie must last as long as the beach period, probably 100 years. There will be no new sand that can be used all the shore erosion.

There should be a sufficient reason for discontinuing the dredging of sand for



commercial purposes from the bed of Lake Erie.

11 - Col. Vogel, District Engineer in charge of the greater portion of the lake shore, I believe, stated at a meeting in Cleveland last week that the State of Ohio could stop the commercial dredging of sand through the simple means of objecting to the issuing of a navigation permit by the Corps. He has so expressed himself to me.

If one will read between the lines in the statements made by the Beach Erosion Board and the Corps of Engineers he will see clearly that these engineers all believe that no further sand should be dredged from the shore and bed of Lake Erie if we are to maintain and rebuild our beaches. They have no authority or control over what the State of Ohio does with its mineral resources of sand.

12 - The removal of the sand from the deep water banks in Lake Erie undoubtedly has a definite effect upon shore erosion. The closer that these banks are to shore and the closer the dredge digs its channel to the shore the greater and more quickly is the destruction of the sand beach.

The currents induced by waves move the sand grains on the lake bottom along the shore and out to considerable depth.

There are other currents moving also along the lake bottom even in deep water. These currents too move sand grains until the bottom arrives at a state of equilibrium. Dump a ship load of sand on a pile on the lake bottom and the grains of sand in the pile begin moving about in the currents until a new surface of equilibrium has been established. The reverse is also true. Dig or dredge a trench in the sand bed. The equilibrium is disturbed and the sand grains move in to fill the trench. This moving of the sand grains extends all of the way in to the shore. Eventually the trench is filled. The grains move out from the shore beach each filling the hole ahead as the entire sand surface moves to fill the trench dredged. In due course of time equilibrium is re-established and sand from the beach, in amount substantially equal to that dredged from the trench in deep water, has moved out toward deeper water. Repeat this day after day, year after year, in 10,000 cubic yard ship loads and the shore sand is gone.

The sand dredges have a tendency to work nearer to the shore than their permits allow. Last year several survey readings were made definitely locating sand dredging much nearer the shore than their permit allowed. When reported to the Corps of Engineers the practice was stopped by the Coast Guard. Unfortunately, observers are not always present when dredging is done and some of it occurs at night.

This is exactly what I saw happen 25 years ago opposite Bratenhal. The dredging operations were stopped but too late.

The State of Pennsylvania had the same situation opposite the beaches on Presque Isle and it stopped the dredging.

13 - The most difficult problem confronting those of us who are trying to stop the loss of the shore lands and structures is how to get the millions of dollars which will be requested to build the shore and beach protecting structures.

The cost per mile will range from 1/2 to one million dollars. Where beaches are also to be built on a sand barren shore another half million dollars per mile will be required.

14 - Congress has passed laws under which it is possible for the Federal Government



commercial purposes from the bed of Lake Erie.

11 - Col. Vernal, District Engineer in charge of the Greater portion of the Lake shore, I believe, stated at a meeting in Cleveland last week that the State of Ohio could stop the commercial dredging of sand through the simple means of objecting to the issuing of a navigation permit by the Corps. He has so expressed himself to me.

12 - It can well be seen from the lines in the statements made by the Beach Erosion Board and the Corps of Engineers that they are clearly not those engineers who believe that no further sand should be dredged from the shore and bed of Lake Erie. It is one to maintain and rebuild our beaches. They have no authority or control over what the State of Ohio does with its natural resources of sand.

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The State of Pennsylvania had the same situation opposite the beach at Presque Isle and it stopped the dredging.

14 - The most difficult problem confronting those of us who are trying to stop the loss of the shore lands and structures is how to get the millions of dollars which will be requested to build the shore and beach protection structures.

The cost per mile will range from \$15 to one million dollars. Some beaches are also to be built on a sand borrow shore another half million dollars per mile will be required.

15 - Congress has passed laws under which it is possible for the Federal Government



to pay 1/3 of the cost for structures required to protect public property. The process for securing this Federal help is not quick or sure.

The Corps of Engineers must make a study of the shore conditions and prepare a report showing how the shore can most economically be protected from erosion. This report upon how to do the protecting can and will include both public and private property. The cost for protecting the public property is determined together with economic justification of such an expenditure. This is all reviewed by the Beach Erosion Board and revised if found necessary. The favorable report, if so it has been found, is sent to Congress for its approval. When the report has been approved by the Congress, it can appropriate funds in the amount not to exceed 1/3 of the cost for the structures to protect the public property for expenditure by the Corps of Engineers.

15 - The General Assembly of Ohio has made \$1,000,000 available for shore erosion work as of the end of this month. The authority limits its use to the protection of publicly owned property.

16 - Neither the Congress nor the State General Assembly has seen fit to provide for the payment of any part of the cost for protecting private property against erosion.

Some legal authorities believe that through the creation of a Conservancy District money can be provided to protect private property. Judge Morgan, the eminent Cleveland attorney, was quoted recently as saying that a modification of the Flemming Act might be a better vehicle.

17 - The General Assembly has provided money for the purchase of land to establish two state parks on the shore of the lake, one east and one west of Cleveland. The purpose of the parks is to provide recreational facilities for the people of Ohio.

They are to give to all Ohioans the benefit of the recreational facilities of Lake Erie such as bathing, boating, fishing or just watching the beautiful sunsets over the lake and enjoying the lake breezes.

These parks will be a reality in 1947 if the present plans of the Governor can be carried out. Each will have a mile or more of shore. At each of the tentative sites there are now splendid banks of lake sand. If this sand can be held along the shore by suitable structures the State will always have fine bathing beaches for the recreational use of all its people.

Perhaps the most effective use which can be made of the money provided by the General Assembly for shore erosion work to be used for the benefit of all the people of Ohio is in the building of structures to prevent the washing away and erosion of the sand and cliffs at the new State lake shore parks.

18 - I found that it was for the best interest of the State and the efficient operating of the Department of Public Works that the headquarters for the Shore Erosion Division be located in Columbus. The office in Toledo was therefore closed as of 30 September 1947. With the headquarters of the shore erosion work in Columbus the work of the Department can be carried on more expeditiously and efficiently.

The shore erosion work of this Department is now a full-fledged operation involving the planning and building of structures in addition to cooperating with the Corps of Engineers and the Beach Erosion Board in the study of the rapidly eroding shore of Lake Erie.



to pay 1/3 of the cost for structures required to protect public property. The process for securing this Federal help is now going on now.

The Corps of Engineers must make a study of the shore conditions and prepare a report showing how the shore can most economically be protected from erosion. This report upon how to do the protecting can and will include both public and private property. The cost for protecting the public property is determined together with economic justification of such an expenditure. This is all reviewed by the Beach Erosion Board and revised if found necessary. The favorable report, if it has been found, is sent to Congress for its approval. When the report has been approved by the Congress, it can appropriate funds in the amount not to exceed 1/3 of the cost for the structures to protect the public property for expenditure by the Corps of Engineers.

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Some legal authorities believe that through the creation of a Governmental District money can be provided to protect private property. Judge Johnson, the eminent Cleveland attorney, was quoted recently as saying that a modification of the Fishing Act might be a better vehicle.

15 - The General Assembly has provided money for the purchase of land to establish a State Park. The land is to be purchased in the State of Ohio. The purpose of the park is to provide recreational facilities for the people of Ohio.

They are to give to all Ohioans the benefit of the recreational facilities of Lake Erie such as bathing, fishing, boating, and just watching the beautiful sunset over the lake and enjoying the lake breezes.

These parks will be a reality in 1947 if the present plans of the Governor can be carried out. Each will have a mile or more of shore. At each of the tentative sites there are now splendid banks of lake sand. If this sand can be held along the shore by suitable structures the State will always have fine bathing beaches for the recreational use of all the people.

Perhaps the most effective use which can be made of the money provided by the General Assembly for shore erosion work is to be used for the benefit of all the people of Ohio in the building of structures to prevent the washing away and erosion of the sand and cliffs at the new State Lake shore parks.

16 - I found that it was for the best interest of the State and the citizens operating at the Department of Public Works that the headquarters for the Beach Erosion Division be located in Columbus. The office in Toledo was therefore closed as of September 1947. With the headquarters of the shore erosion work in Columbus the work of the Department can be carried on more expeditiously and efficiently.

The shore erosion work of this Department is not a full-fledged operation involving the planning and building of structures in addition to cooperating with the Corps of Engineers and the Beach Erosion Board in the study of the rapidly eroding shore at Lake Erie.



The office in Toledo has been a convenient place and location to carry on the work, but it is not at all conveniently located for cooperation with the Buffalo District Office of the Corps of Engineers in which District is located the greater portion of the shore of Lake Erie.

Mr. F. O. Kugel, my engineering assistant, has been designated to act as the Department's representative in the cooperative studies with the Corps of Engineers on the Shore Erosion problems in place of Mr. Gould of Toledo.

Mr. Gould will continue to work for the Department from his home in Toledo. He has several unfinished reports to be prepared. He will also be used in connection with the study and planning of shore protection and beach holding works.

In order to reduce the cost of the shore erosion study and survey as well as to expedite this work so that we may have the results sooner, it has been agreed that the Corps of Engineers will do such "base line" and topographic survey work as may be required for the several studies.

The District Engineer reports that much of the "base line" and "shore point" location work performed by the State has not fitted into their shore and lake survey work thereby requiring that a considerable portion be re-run by the Corps. The shore topographic survey work can be more efficiently done by the Lake Survey Office of the Corps of Engineers and serve a double purpose with a resulting saving to the State.

The County Engineers of several counties along Lake Erie have furnished excellent surveying work when they have had the field parties available and not busy on their own county work and within their limited knowledge of what the Corps of Engineers required. This cooperative work of the several lake counties will no longer be required in conjunction with the Federal studies.

19 - At a recent conference in Buffalo with the District Engineer it was agreed that the entire Ohio shore of Lake Erie would be divided into 15 sections for purposes of study and planning.

The study and recommendations for Sec. I have been completed and published. H.D. 177, 79 Congress. The section from the Michigan State line to Marblehead and about 60 miles long. The Board reported that the protection of the shore against erosion can be achieved when economically justified. It further recommended that no share of the expense of any improvement of this shore line outside the limits of Camp Perry should be borne by the United States.

The study and report for Sec. VI has also been completed and published. H.D. 220, 79 Congress. The section in the vicinity of Huron and about 20 miles long. In this section the Board reported that beaches may be built only by artificial supply. The Board also determined that there was no Federal interest involved and that no share of the cost should be borne by the United States.

Section III is now under study. It is about 12 miles of shore east of Painesville.

Sections VIII and IX will next be undertaken. They are at the locations for the proposed State parks. A total of about 28 miles.

Section IV is a short length of shore on Sandusky Bay. The field work has been completed and the report is being prepared.



The office in Toledo has been a convenient place and location to carry on the work, but it is not as conveniently located for cooperation with the District Office of the Corps of Engineers in which District is located the greater portion of the shore of Lake Erie.

Mr. F. O. Engel, my engineering assistant, has been best suited to act as the Department's representative in the cooperative studies with the Corps of Engineers on the Shore Erosion problem in place of Mr. Gould of Toledo.

Mr. Gould will continue to work for the Department from his home in Toledo. He has several unpublished reports to be prepared. He will also be used in connection with the study and planning of shore protection and beach building works.

In order to reduce the cost of the shore erosion study and survey as well as to expedite this work we have the various papers, it has been agreed that the Corps of Engineers will do such "base line" and topographic survey work as may be required for the several studies.

The District Engineer reports that much of the "base line" and "shore point" location work performed by the State has not fitted into their shore and lake survey work thereby requiring that a considerable portion be re-run by the Corps. The shore topographic survey work can be more efficiently done by the Lake Survey Office of the Corps of Engineers and serve a double purpose with a resulting saving to the State.

The County Engineers of several counties along Lake Erie have furnished excellent surveying work when they have had the field parties available and not busy on their own county work and within their limited knowledge of what the Corps of Engineers requires. This cooperative work of the several lake counties will no longer be required in conjunction with the Federal studies.

At a recent conference in Buffalo with the District Engineer it was agreed that the entire Ohio shore of Lake Erie would be divided into 15 sections for purposes of study and planning.

The study and recommendations for Sec. I have been completed and published. M.D. 177, 79 Congress. The section from the Michigan State line to Highland and about 60 miles long. The Board reported that the protection of the shore against erosion can be achieved when economically justified. It further recommended that no share of the expense of any improvement of this shore line should be borne by the State of Ohio.

The study and report for Sec. VI has also been completed and published. M.D. 280, 79 Congress. The section in the vicinity of Huron and about 30 miles long. In this section the Board reported that beaches and dunes should be built by artificial supply. The Board also determined that there was no Federal interest involved and that no share of the cost should be borne by the Federal Government.

Section III is now under study. It is about 14 miles of shore east of Fairport.

Sections VIII and IX will next be undertaken. They are at the locations for the proposed State park.

Section IV is a short length of shore on Sandusky Bay. The field work has been completed and the report is being prepared.



The Cleveland Section work is not being sponsored by the State. I believe that the report is promised for early next year.

The Corps of Engineers believes that it can complete 3 to 4 reports per year on Lake Erie in addition to work within Pennsylvania and New York States. At this rate of progress it will require about 3 years to complete the Ohio studies.

The Corps of Engineers is cooperating splendidly in hastening and expediting the study and report upon those two sections of shore within which the State will establish the two Lake Shore parks.

The Beach Erosion Board has been asked to expedite its work and recommendations in the hope that a favorable report can be made to the Congress for Federal aid since at each site the State of Ohio probably will own at least one mile of lake frontage.

Under existing Federal law the Congress can provide funds to pay 1/3 of the cost of the construction work required to protect publicly owned property.

19 - The erosion cancer which is eating away the shore of Lake Erie can be cured. It will be a costly undertaking. The cure has been started.

It is hoped that a downward cycle of the lake level will begin next year. Any lowering of the lake will reduce the erosion but it is not a cure.



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The Senate Section Board has been asked to expedite its work and recommendations in the hope that a favorable report can be made to the Congress for Federal aid since at least the State of Ohio probably will not at least pay a share of the project.

Under existing Federal law the Congress can provide funds to pay 1/3 of the cost of the construction work required to protect publicly owned property.

19 - The erosion danger which is eating away the shore of Lake Erie can be cured. It will be a costly undertaking. The cure has been attempted.

It is hoped that a downward cycle of the lake level will begin next year. Any lowering of the lake will reduce the erosion but it is not a cure.



Influence of Vegetal Cover in Flood ControlA Panel Discussion

By

W. C. Lowdermilk

In this discussion we are examining the role of vegetal cover in flood control. The question has been under discussion for more than a century, but it is only in the last two decades that experimental studies have yielded quantitative information bearing upon it.

It is a question to which the answer can be determined only by a comparison of the run-off from land under widely variable conditions of cover. In other words, it is impossible to consider the role of vegetal cover without considering at the same time a full range of land surface conditions under all possible types of land use. We must consider the relative differences between the effect of forest, grass, and cultivated fields, on storm run-off as it gives rise to floods.

We must, then, examine by drainages the relation of land use patterns to the behavior of run-off waters, both as to amount and rate. Simply stated, our problem is to ascertain, on a drainage basis, what types of land management will contribute most to the regulation of storm run-off. Such land management must provide, of course, for the necessities of dependent populations; it must allow for the clearing and cultivation of land for food and fibre crops; and it must be open to progressive improvement as a means of increasing the absorption of meteoric waters, the retardation and detention of unabsorbed waters, and the control of silting and accumulations of erosional debris.

The flood phenomenon is the climax of a series of natural events. It results from antecedent and contemporary meteorological conditions, which provide precipitation waters in excess of the absorptive capacity of the tributary land surface. Unabsorbed waters are moved by the force of gravity over the land surface as excess surficial flow, filling up detention storage until the residual waters are assembled and delivered through a net work of tributaries to the major waterways, such as this Ohio River. It must be recognized that there is law and order in the sequence of these events and that a flood bears a cause-and-effect relation to an intricate set of variable conditions.

To simplify the approach to the problem under consideration, I am distinguishing between ground water run-off and surface water run-off resulting from flood producing storms. It is storm run-off which contributes most to flood flows and which in turn offers the greater opportunity for modification by different types of land use. For that reason attention is directed to storm surface run-off.

The possible influence of vegetal cover on storm run-off involves three major factors, each of which must be examined separately







if we are to avoid the pitfalls into which students of this problem have fallen for nearly a century. These three factors are first, the infiltration or absorptive capacity of the land within a drainage; **second**, the progressive concentration of unabsorbed storm waters from drainage channels into trunk streams; and third, the accumulation of erosional debris in stream channels. It is my contention that these three factors are so different and independent of each other in their influence upon flood flows that any attempt to combine them in measuring the influence of land surface conditions on flood flow is doomed not only to confusion but to highly questionable and unreliable results. In the past, most studies, beginning with the Basin of Ru de la Grone-tiere by the famous French engineer, Belgrand, have not separated these three factors. As a consequence, the literature still refers to conclusions based upon studies which cannot be fully relied upon. The results are divergent; and the conclusions conflicting as well.

These three factors namely, the absorptive capacity of the land, the concentration of unabsorbed waters, and accumulations of erosional debris, must be studied separately. The mechanism of a flood must be taken apart, its parts examined and measured. Then when we put them together again, it may be possible to discover how far the conditions of land cover may ultimately affect flood flows. In my opinion, until we do this we shall continue to flounder in the maze of confusion that has marked this branch of knowledge up to the present.

Fortunately significant progress is being made which promises to yield dependable information on which to base measures and practices of land management which will give the maximum control in erosion and storm run-off and in turn of flood flows, to supplement and to safeguard the necessary large scale engineering works of flood detention and flood protection in stream valleys subject to inundations.

A large body of data on the first factor, namely infiltration capacity of the land, is accumulating from a series of erosion and run-off experiment at soil erosion and forest experiment stations. These studies are supplying information on the rates and amounts of infiltration into various soils under different conditions of natural and artificial cover on different slopes. The significant progress to date, however, marks only a beginning in evaluating the several factors which determine the rate and capacity of intake of water by soils under optional methods of use.

Let us examine more specifically the role of vegetal cover in affecting storm run-off. Coming down through the literature from the earliest considerations of the influence of forests on climate and water is this concept of vegetal cover as the dominant influence on flood flows.

Attention has been given to the more obvious functions which vegetal cover performs such as, canopy interception, mechanical ef-







fect upon surface velocities, surface detention and absorption by litter, effects on the melting of snow, on the freezing of soil, and effects in utilizing soil moisture. Most of these studies seem to have assumed that vegetal cover is the principal agent of absorption of rainfall.

But two important omissions have generally been made. First, during flood-producing precipitation the functions of the vegetal cover in these respects is soon overtaxed; and, second, the soil and underlying material rather than the vegetal cover is the principal agent of absorption of meteoric waters within a drainage basin. Thus the question resolves itself down to what part vegetal cover plays in determining the intake and absorption of waters of the soil.

On the basis of comprehensive experimentation hitherto reported, the unquestionable conclusion is that interception and absorption by a vegetal cover is, on the one hand, relatively unimportant during heavy precipitation; but that, on the other hand, vegetal cover is decisively important in maintaining a soil at its maximum capacity to absorb meteoric waters. During flood-producing precipitation the vegetal cover will exert a minor influence on storm flows by absorbing water, but it plays a highly important and decisive role in maintaining the soil at its maximum intake capacity.

The importance of this function becomes apparent when we consider the water-holding capacity of the soil column. The soil and substrata above the water table is second only to the ocean as a reservoir of water. Meinzer reports an average water-table depth of 37 feet, based on data from 28,797 wells. The capacity of this zone of aeration exceeds the heaviest possible fall of rain, and generally exceeds total annual rainfall. Only in bottom lands with ground water near the surface, representing a very small percentage of the land area, would such a generalization be incorrect. Generally the land has the capacity to absorb all precipitation values directly if rates of intake are equal to rates of fall or application. It is the differential in the rates of supply over infiltration which creates the problems of storm run-off.

But lands must be cleared and cultivated; the insistent needs of the hosts of humanity compel it; and this even if the cultivation process harbors the seeds of soil destruction. The full effects of accelerated erosion, of clearing and cultivation of lands to crops have been obscured by abandonment of lands and population shifts. Only in a comparatively small area of the earth's surface has permanent agriculture in tilled crops been thus far achieved, although shifting cultivation has spread over most of the land. The role of soil erosion in land settlement has not yet been adequately studied or understood. It has been discovered in the erosion run-off experimentation of the past decade and more that the clearing and cultivation of lands formerly protected by a natural vegetal cover increases the coefficient of immediate run-off to astounding ratios, and this augmented surficial







run-off washes off with it remarkable amounts of soil. The generalized figures indicate that the ratio of run-off is increased 7 fold; it is far more in light rains and was found to be more than 3 fold at the Zanesville, Ohio Erosion Experiment Station. The hazards of cultivation exceed the hazards of forest management and regulated grazing of grasslands in run-off potentials from heavy storms.

Moreover the hazard in the cumulative effect of erosional debris in stream channels and reservoirs is far greater than in the potential of run-off. The products of accelerated erosion under the dynamic action of increased run-off from cleared or bared sloping lands represents an augmenting menace to the orderly control and use of waters as well as protection against floods.

We now wish to consider the second factor referred to, namely the concentration of flood flows; it is the most elusive aspect of flood stages. I mean to say that in considering the influence of vegetal cover, the factor of variations in the accumulation of water in tributary channels is usually overlooked. The major factor of the behavior of unabsorbed water in its flow from land surfaces is subject to many possible variations. Such variations, for example, involve the synchronization of flow or the lack of it, and the differential travel of flood waves as compared to rate of stream flow. Unless this part of the mechanism of a flood is fully examined and accounted for, we may be misled in our conclusions on the influence of vegetal cover on flood flows. The pattern of a drainage system sets the stage for a wide variety of flood flow behaviors responsive to different rainfall intensity patterns occurring at different seasons of the year. So variable may be these responses that the effects of the land surface condition may be lost in this maze of resulting flood stages in the trunk stream.

In this connection a basic principle of the flood wave phenomenon was developed by James A. Seddon through observation and experiment on the Mississippi and Missouri Rivers preceding 1899. Further work on the progress of a flood wave downstream was conducted by Professor Harold A. Thomas, then at Rose Polytechnic Institute, after the 1913 Ohio flood. He had been besieged for expert testimony by plaintiffs in suits against the railroads on the question of how the flood waves might have acted if the constrictions to free flow offered by the bridges had not been present. Professor Thomas is continuing his work in the Carnegie Institute of Technology at Pittsburgh. Valuable contributions, both through experiment and application of the basic principle, have also been advanced by Mr. Leroy K. Sherman in studies of the Illinois (1923) and Delaware (1931) rivers. Closely associated with this line of investigation is a detailed study of rainfall patterns of individual storms within a drainage such as was used by Dr. A. E. Morgan in the study of the Miami flood of 1913 and the Miami flood control project which has met every test thus far.







Thus it is apparent that the contrasts in run-off from land surfaces under different conditions of use as measured on small experimental plots may diminish progressively down stream as a result of the variable responses of stage heights to different and changing rainfall patterns and differential movement of flood waves. The results from the smaller experimental areas may not have areal significance for large drainages. And until the behavior of storms and the patterns of intensity and amount of rainfall are known and the characteristics of flood flow accumulations can be charted, the influence of the comparative condition of land surfaces on flood flows cannot be determined by stream gaging.

It is necessary, however, to record the fact that studies of this factor are under way and promise significant findings, as Bernard has shown.

Finally, for consideration in determining the influence of vegetal cover upon floods, the third of the major factors, namely, the problem of accelerated soil erosion and the effect of attendant sedimentation upon stream channels and detention reservoirs deserves our consideration. The influence of vegetal cover in reducing soil losses by erosion has been definitely established through a long series of experiments at the erosion and forest experiment stations. The fact that much of the damage caused by the deposition of erosional debris, particularly in stream channels and storage reservoirs, is cumulative from one flood period to another, makes it especially pertinent that this phase of flood damage be given special consideration.

It is possible that vegetal cover may make in time a far greater contribution toward the mitigation of flood damage by lessening the amount of material deposited than in the actual reduction of flood flows.

Eakin has called attention to the significant adjustments of stream and valley features to the increased stream load of erosional debris derived from accelerated erosion of drainage basins. The effects on floods is brought about in the reduced channel cross section and configuration. And, furthermore, the aggregate volume of debris load in transport from place to place in the channel affects fundamentally the volume of the current as well as its velocity. In time the cumulative effect may so alter the channel characteristics and capacity as to jeopardize the effectiveness of downstream flood detention and control structures, as has been the case in the Huang Ho and Hwai Rivers of China and of many tributaries of the trunk streams in the United States.

It is doubtful if we are yet equipped to trace the influence of conditions in a given drainage area through to the flood stage in a trunk stream. However, for purposes of discussion let us attempt







to analyze the 1937 Ohio flood on the basis of estimated coefficients of run-off for the various land uses. Taking an average of twenty occurrences from small watersheds representing cultivated, pastured and wooded areas on two of the erosion experiment stations of the Soil Conservation Service, we find that for storms of flood producing intensities the coefficient of run-off averages 74, 30, and 11 respectively for these three uses. In other words, an approximate run-off potential of 7, 3 and 1 for cultivated, pasture and woodland respectively, is indicated for these particular small areas (all less than 35 acres). This ratio, however, is derived from averages of all rains falling throughout a year. They would not be valid for prolonged heavy storms.

We know also that on large watersheds under conditions of heavy prolonged rainfall the range of these ratios will diminish. Based on results of measurements from small areas at Zanesville, Ohio, we may estimate a run-off coefficient of 66-94 for fields in winter condition, and 25-30 for grassland and forests for the January 1937 storm period. The flood run-off potential from small areas was 3-1-1. It is of special note that the grass cover under heavy rains approaches in effectiveness a forest cover in favoring infiltration and control of erosion as well.

The distribution of land use for the Ohio Valley has been computed from surveys to be as follows:

|                      |             |
|----------------------|-------------|
| Cropped lands        | 33 per cent |
| Pasture - grassland  | 29 per cent |
| Urban road, etc.     | 5 per cent  |
| Forests and woodland | 33 per cent |

Thus the distribution of use is about equally divided between cropped land, grassland, and forest. Applying the run-off potential ratios from the small experimental areas to the entire drainage the run-off coefficient becomes 45%.

Indications are, on the basis of stream gaging, that 7 to 8 inches of surface run-off occurred for the entire drainage basin during this flood period. Weather Bureau data indicate an average fall of 11.3 inches of precipitation for the storm period giving rise to the flood. The indicated run-off coefficient approximates 66% run-off for the basin as a whole. Thus the stream discharge as estimated from gaging stations was about 20 percent in excess of that based computations from small plots. A number of factors may account for this difference in quantity which must be distinguished from the question of stage heights. It goes to emphasize the need for bridging the gap in an information of what happens between the small measured experimental areas and the trunk stream.

If such a flood potential ratio as suggested above is anywhere







near correct, it can be readily seen that the greatest gains in reducing flood flow is by treating the cultivated lands, either by vegetative or mechanical means according to the needs and adaptabilities. The flood run-off hazard is found to be much higher on the cultivated lands than on the forested or grass pasutre lands. The larger returns both in run-off coefficients and in erosional debris production will be had by the treatment of the cultivated slopes of the Ohio drainage with soil and water conservation measures.

Nevertheless, I have previously stated, because of deficiencies in our information on fundamental hydraulic laws which govern the assembly and propagation of flood waves and the synchronization of flood flows in a river system, I doubt if we have sufficient knowledge to give true areal significance to the influence of vegetal cover in the manner just illustrated. But we can see through the maze to a time when we shall be ready to do so perhaps within a few years. Such studies as are now under way at San Dimas, California, at Coshocton in the Muskingum Conservancy District in Ohio, and at Waco in the Brazos flood control district in Texas, and elsewhere are designed to integrate these factors.

To have our problem broken down into its essential factors; to have those factors defined and isolated for experimental study, will make possible a synthesis of the several values for a solution to the problem of the influence of land surface conditions upon flood flows under various conditions of storm intensities at different seasons of the year. Not until then can the influence of various types of land use on flood flows be known.

May 31, 1937







PERFORMANCE OF FLOOD PREVENTION WORKS  
DURING 1957 SPRING FLOODS

Performance of watershed protection and flood prevention works in Arkansas, Oklahoma and Texas during the severe storms and floods of April, May and June, 1957, will be discussed in this paper.

The watershed protection and flood prevention work of the Soil Conservation Service is done in cooperation with Soil Conservation Districts and other State subdivisions such as Watershed Districts, Conservancy Districts, Water Control and Improvement Districts, Levee Districts, Drainage Districts, Irrigation Districts, and others. A watershed protection and flood prevention program includes proper land use and treatment in combination with structural works of improvement such as floodwater retarding structures, floodways, channel improvement, floodwater diversions, and sediment control and grade stabilization structures.

Watershed protection and flood prevention work is being carried on under three different authorizations. The Flood Control Act of 1936 included authorization for works of improvement in the Washita River watershed in Texas and Oklahoma, and the Trinity and Middle Colorado River watersheds in Texas. A "pilot" watershed program, implemented by an item in the 1954 Appropriation Act, included the Six Mile Creek watershed, Arkansas; Double Creek watershed, Oklahoma; and the watersheds of Green, Calaveras and Escondido Creeks and Cow Bayou, Texas. Expansion of watershed activities nationwide was authorized by Public Law 566, enacted in 1955, but operations had only started in a few watersheds in this area by the time of the 1957 storms.

Between 1951 and 1957 Oklahoma and Texas suffered the most severe drouth of record. Consequently, watershed cover conditions were far below normal over much of the area when the 1957 spring storms occurred.

Excessive rainfall began on April 19 and continued through most of June. Rainfall exceeding 150 percent of normal occurred in Texas, Oklahoma and western Arkansas during April and May, 1957.

During this critical storm period from 35 to 40 inches of rainfall were recorded at several locations. The mean depth of rainfall over the three states was 19 inches. This is equivalent to 445 million acre-feet of water, or enough to fill the flood control pool of Lake Texoma 165 times.

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Prepared for presentation at 1958 Annual Meeting, ASAE, Santa Barbara, California, by Howard Matson, Head, Engineering and Watershed Planning Unit, Soil Conservation Service, Fort Worth, Texas.  
USDA-SCS-FORT WORTH, TEX. 1958







Maximum daily rainfall generally ranged from 4 to 10 inches. The maximum 2-day rainfall of 20 inches occurred at Hennessey, Oklahoma. Monthly maximums recorded were 20.48 inches at Glenfawn, Texas; 22.38 inches at Hennessey, Oklahoma; and 19.07 inches at Sparkman, Arkansas. The weighted rainfall on the Honey Creek watershed, Texas, was 30.5 inches in 37 days, April 19 to May 26.

Figure 1 shows an isohyetal map of rainfall for the 3-month period. Figure 2 shows the location of a number of watershed projects in which works of improvement for watershed protection and flood prevention had been completed or were in progress.

Total runoff for the 3-month period far exceeded previous records for both large and small drainage areas. Table 1 shows a comparison, for several watersheds, of the 1957 April-May-June runoff with the mean runoff for that period.

TABLE 1

April-May-June Runoff  
Watershed-Inches

|                                       | <u>1957</u> | <u>Mean</u> |
|---------------------------------------|-------------|-------------|
| Little River (Horatio, Ark.)          | 20.0        | 7.4         |
| East Fork, Trinity River (Lavon Res.) | 16.7        | --          |
| Trinity River (Dallas, Texas)         | 11.5        | 1.6         |
| Red River (Fulton, Ark.)              | 11.4        | 2.1         |
| Washita River (Durwood, Okla.)        | 5.8         | 1.5         |
| Cimarron River (Perkins, Okla.)       | 3.1         | 0.5         |

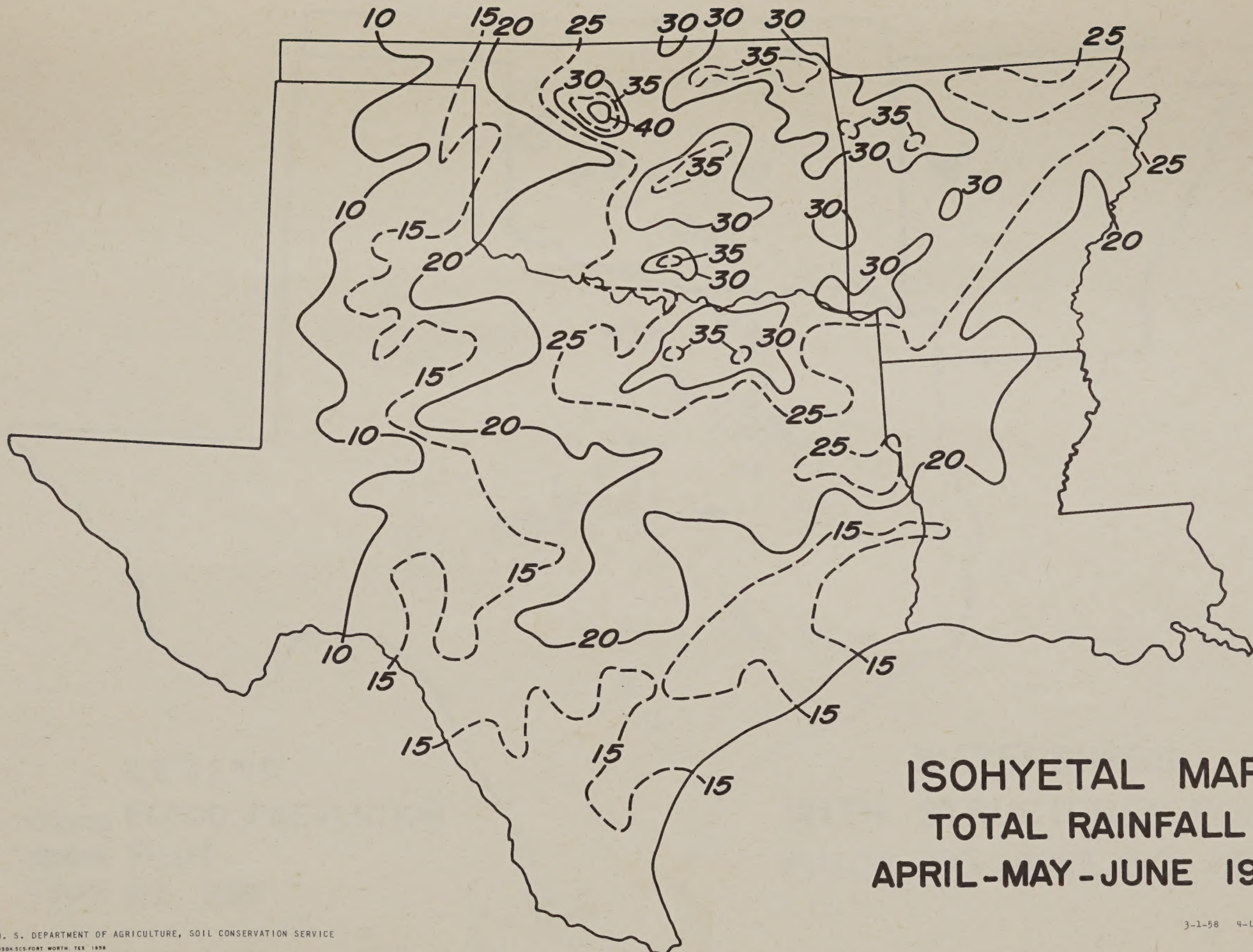
The runoff from the series of storms inundated 11,575,000 acres of flood plain lands along the tributary streams in the 3-state area, causing damages estimated at more than \$156,800,000. Ten lives were lost in creek floods in Texas; four in Oklahoma.

There were 367 upstream floodwater retarding structures in operation in this area, with a combined flood detention capacity of about 285,200 acre-feet. Of these 195 were in Texas, 149 in Oklahoma, and 23 in Arkansas. Through the process of filling, releasing and refilling during the storm period the structures detained and released in an orderly manner about 534,800 acre-feet of floodwater. If all feasible tributary watershed work for flood prevention had been completed it is estimated that 33 million acre-feet of detention storage would have









# **ISOHYETAL MAP** **TOTAL RAINFALL** **APRIL-MAY-JUNE 1957**







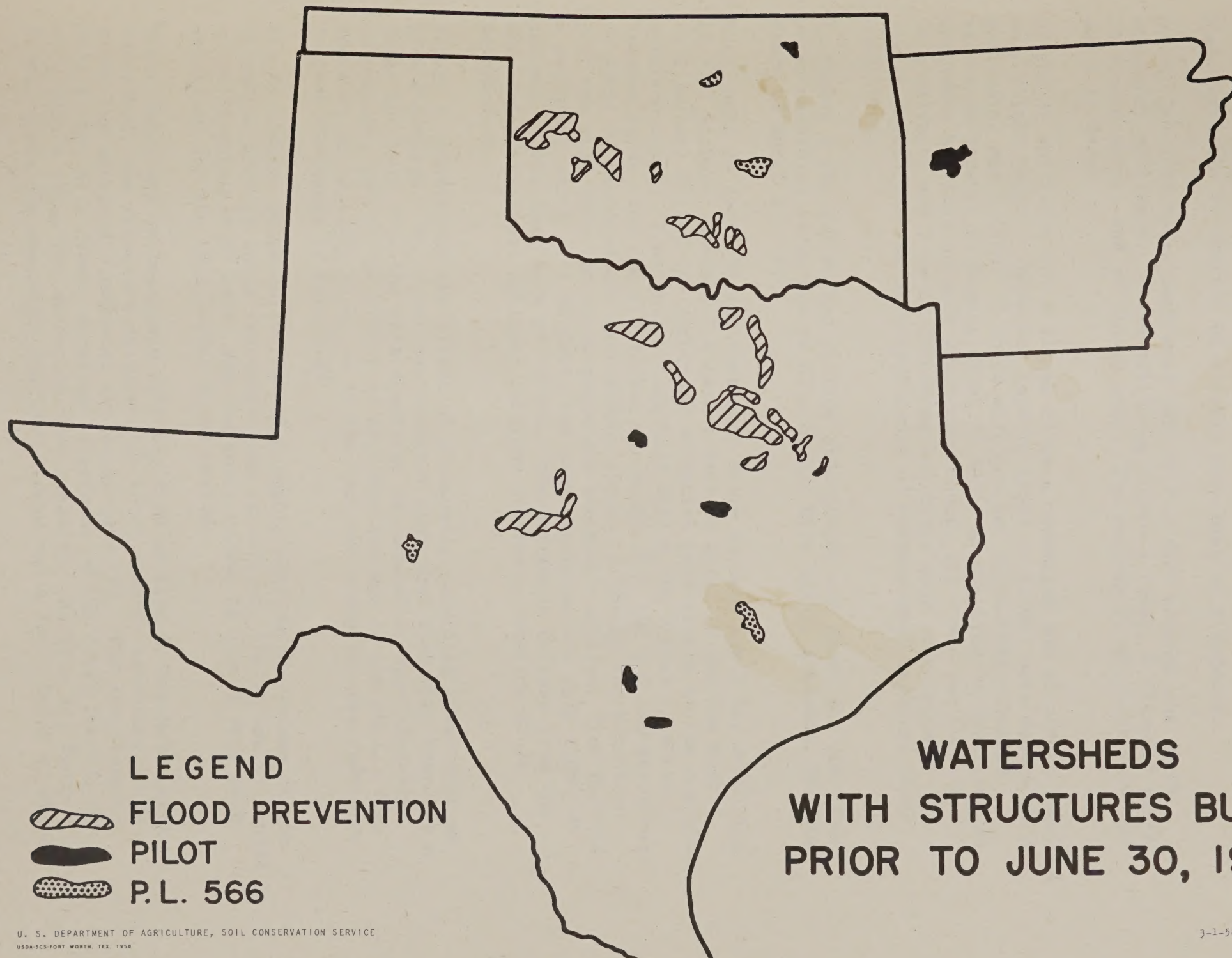


Figure 2







been available to control 62 million acre-feet of floodwater.

Of the 367 structures mentioned only 99 had flow through the earth emergency spillways. Three spillways flowed 4 times, 8 flowed 3 times, 23 flowed twice, and 65 flowed once. The maximum duration of flow was about 14 days.

Of the 99 spillways which flowed 62 were undamaged and 23 others required only slight repair. Moderate repairs (\$500 to \$1200) were needed on 9 spillways, and 5 (four of which were not yet vegetated) required extensive repairs averaging about \$5,000. At the time of the flows 53 spillways had fair to good vegetative cover; the cover was poor on 38 spillways; and 5 newly-completed spillways were unprotected. The severe drouth was the principal cause of below-normal spillway cover conditions.

In Figure 3 the inflow and outflow hydrographs are shown for the floodwater retarding structure at Site 6, Six Mile Creek, Arkansas, for the storm of April 27, 1957.

Rain began on April 18 and continued daily through April 24, amounting to 3.53 inches. Another 2.4 inches fell on April 26 and the runoff (2.2 inches) filled the structure detention pool nearly to the emergency spillway crest. Pool inflow continued during the 9-hour interval between rains, and the 1.8 inches of runoff from the 2.0 inches of rain on April 27 produced the hydrographs shown. Although the detention pool was full when the storm began and emergency spillway flow reached a momentary depth of 1.45 feet, the peak discharge was only about 40 percent of the peak rate of inflow. The automatic release from the drop inlet principal spillway remained virtually constant at 24 second-feet.

Figure 4 illustrates the effect of floodwater retarding structures on peak discharge. The first two examples show that even when there is a large spillway flow the peak discharge is reduced by approximately 50 percent, due to the effect of spillway storage in the pool. When there is no spillway flow, as in the last two examples, the reduction in peak discharge is very high.

Figure 5 shows graphically the relationship between the volume of the detention pool of three representative structures, the volume of runoff actually detained by each, and the total volume of runoff from each watershed for the three-month storm period.

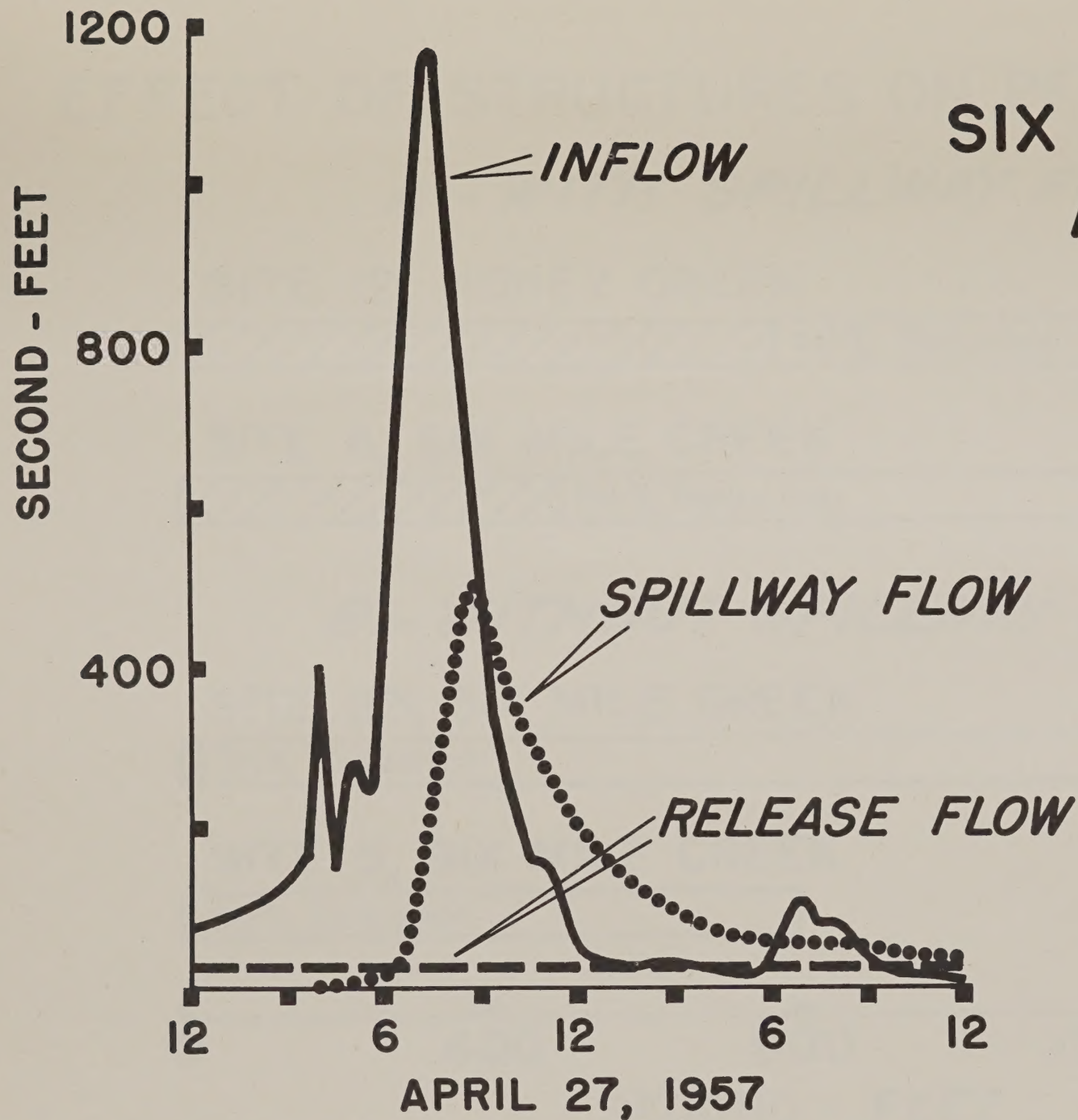
Since there was no emergency spillway flow at Site 2, Six Mile Creek watershed, the structure detained the total runoff, amounting to  $3\frac{1}{2}$  times the designed floodwater retarding capacity. The structure at Site 6, Six Mile Creek, detained 94 percent of the total runoff, or more than 4 times the detention pool capacity. At Site 12, Honey Creek, where the emergency spillway flowed twice for a total of about







**SITE 6  
SIX MILE CREEK  
ARKANSAS**





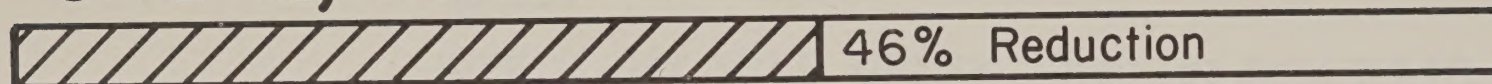




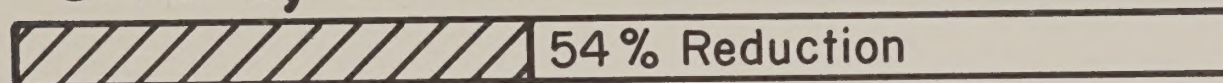
# EFFECT OF STRUCTURES ON PEAK DISCHARGE

## *A - WITH SPILLWAY FLOW*

SITE 12, HONEY CREEK

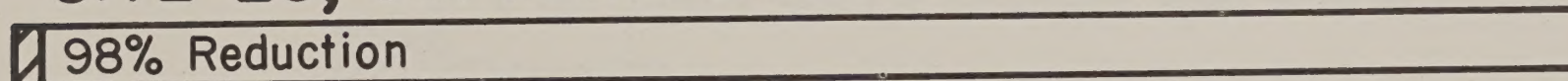


SITE 6, SIX MILE CREEK

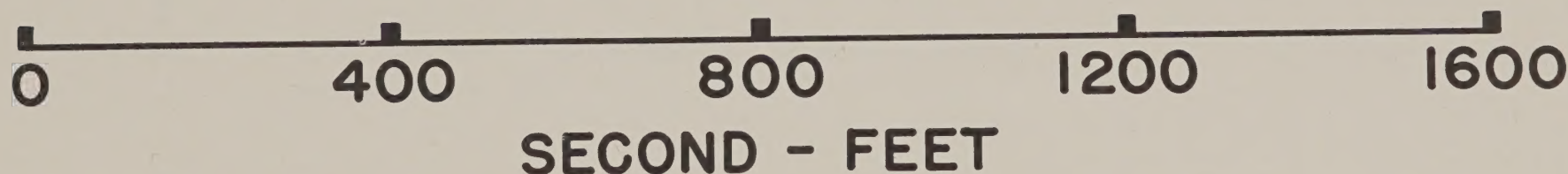
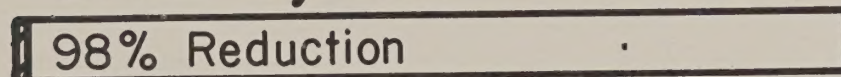


## *B - WITHOUT SPILLWAY FLOW*

SITE 23, SIX MILE CREEK



SITE 5, SIX MILE CREEK









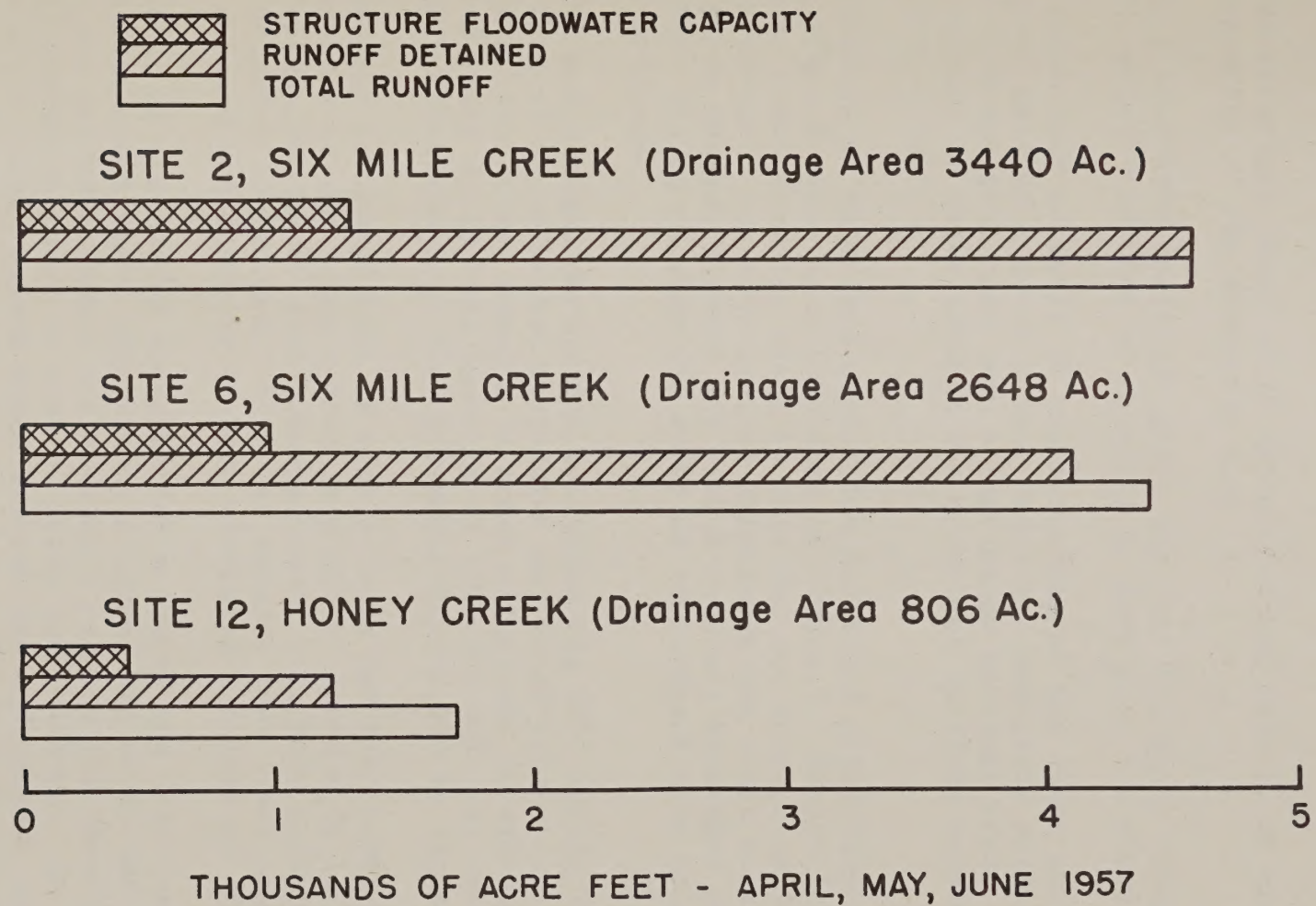


Figure 5







10 days, the structure detained 71 percent of the runoff, or almost 3 times the capacity of the detention pool.

Figure 6 is a structure operation graph for Site 12, Honey Creek, for the 3-month period. Amounts of rainfall by days also are shown.

The graph shows that on April 24 the elevation of the water surface in the detention pool reached a point 3 feet below the emergency spillway crest, and that it did not fall more than 4 feet below spillway crest for 42 days. Automatic release of water through the principal spillway continued from April 19 through June.

The effectiveness of watershed protection and flood prevention work in preventing flood damages is illustrated in Figure 7. Except in the Chigley Sandy Creek example, which is only for one storm, the data cover the 3-month period. For four typical watersheds the chart contrasts estimated flood damages without and with a complete watershed program. Other benefits resulting from the works of improvement were not considered in this analysis.

Studies of flood damages during and following the 1957 spring floods indicated that if no watershed protection and flood prevention work had been done the total flood damages in creek watersheds in Arkansas, Oklahoma and Texas would have amounted to \$159,208,000. It was estimated that the work which had been done prevented \$2,162,000 in flood damages.

Further analysis indicated that if similar work had been completed in all creek watersheds in the 3-state area in which it appears to be feasible, a total of \$109,320,000 of flood damages would have been prevented, or a reduction of about 70 percent. Also, it appears that flood peaks would have been reduced sufficiently to have prevented the loss of the 14 lives.

A high percent of the needed conservation measures and practices had been applied in watersheds where improvement programs are under way. However, the severe and extended drouth had seriously reduced the amount and quality of vegetative cover in most of Texas and Oklahoma. As a result, during the April storms upland sheet erosion was widespread, and severe in many areas. Cover conditions improved rapidly throughout the area during the storm period, and a reduction in the amount of sheet erosion from the storms in late May and June was very evident.

Studies were made in Texas to determine the effect of cover and soil condition on the depth of moisture penetration during the storm period. In April and May 133 paired borings were made on conservation-treated and unprotected areas with otherwise similar conditions, on cropland, range and pasture. Although there was wide variation in the depth of penetration under the different land use, soil and rainfall conditions, the average was twice as great on protected land as on unprotected.







# STRUCTURE OPERATION GRAPH

## SITE 12

### HONEY CREEK, TEXAS

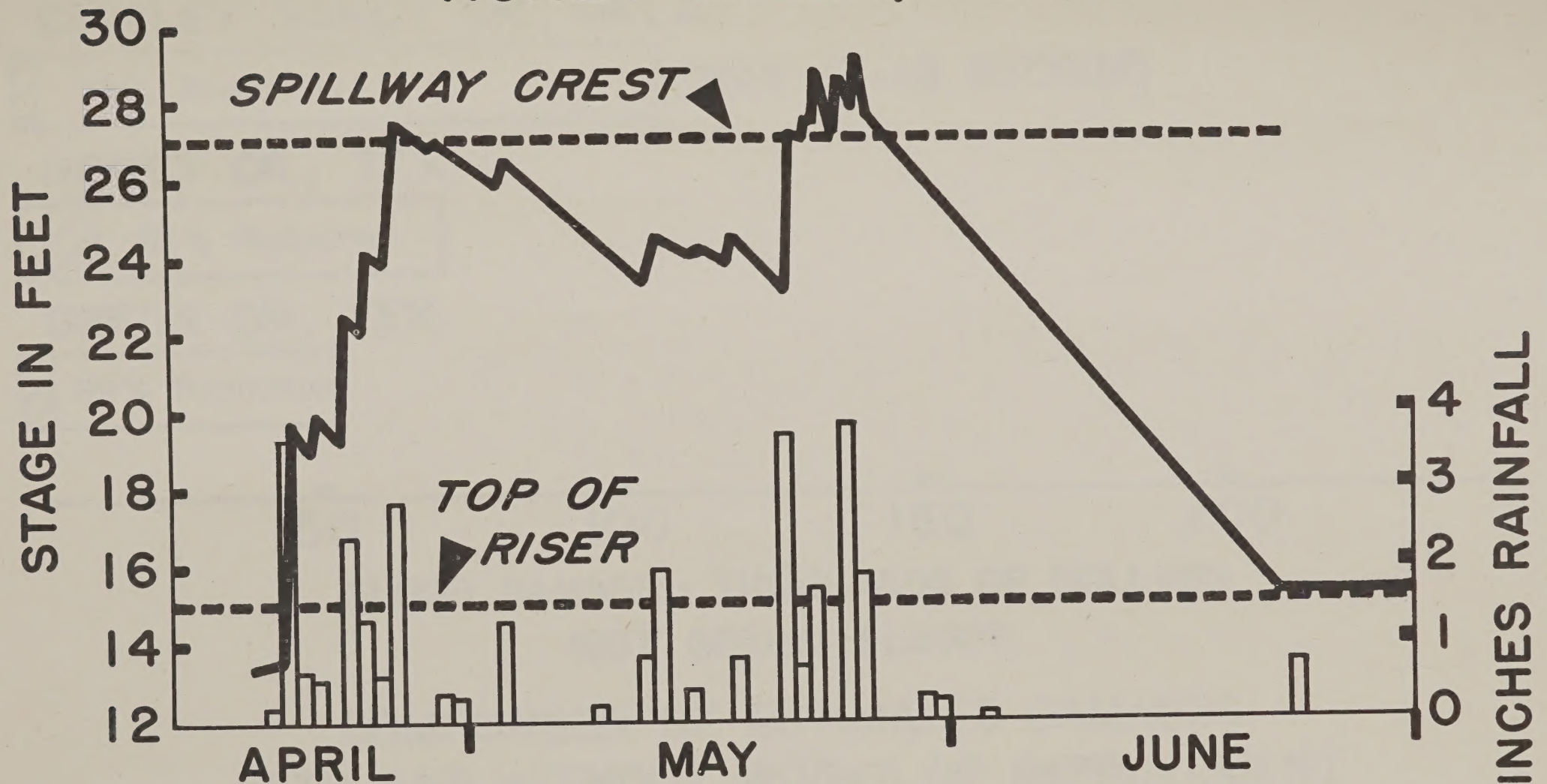


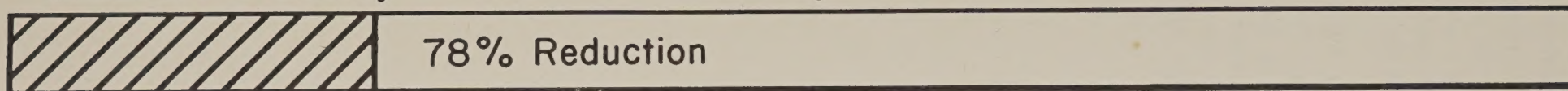
Figure 6



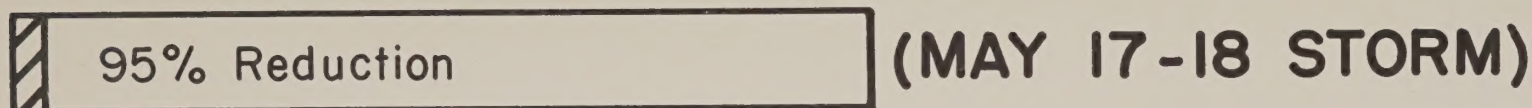




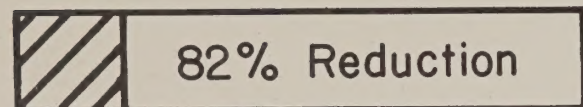
## CLEAR FORK, TRINITY RIVER, TEX.



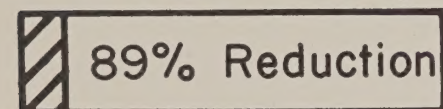
## CHIGLEY SANDY CR., OKLA.



## HONEY CR., TEX.



## GREEN CR., TEX.



50

100

150

200

FLOOD DAMAGE - THOUSANDS OF DOLLARS  
1957 SPRING FLOODS

COMPARISON OF ESTIMATED DAMAGES  
WITH AND WITHOUT WORKS OF IMPROVEMENT







The performance of the watershed protection and flood prevention work exceeded expectations during this unprecedented series of intense storms, and no major changes in methodology or design criteria appear to be needed. A large amount of valuable technical data was collected, and from its analysis we hope to develop worthwhile refinements and improvements in planning and design procedures.

The 1957 spring storms in Arkansas, Oklahoma and Texas provided a severe test of watershed protection and flood prevention work, and fully demonstrated the effectiveness of protection measures in reducing flood damages. The adequacy and safety of the structure designs were evidenced by the fact that no structures were in danger of failure as a result of these intense successive storms.







A-17

## SOIL CONSERVATION AND FLOOD CONTROL<sup>1</sup>

FLOODS-FLOOD CONTROL

I am especially glad of this opportunity to join with you in this flood control celebration with Cloud Creek sub-watershed of the Washita Valley. It was a long time before the type of flood control work being done here -- although long needed -- was finally recognized formally through Congressional approval, in the Flood Control Act of 1936.

I also am proud that I was able to have some part in the events that resulted in making upstream watershed conservation a recognized part of our national flood control program. And it naturally gives me much satisfaction to come out here into such a watershed and see our broadened flood control approach being put into action, the way I saw the work being done on a trip over part of the watershed yesterday, and the way you can see it for yourself here in this reservoir detention phase of the work.

This illustrates what I have long felt is the true situation about floods, namely: Flood control is a job which begins where the rains fall and runoff starts, and ends only when that runoff has safely reached the ocean.

We have come here today to give recognition to one of the most important developments in our agricultural history, but on this particular occasion the purpose of our visit is twofold. First, we are here to see for ourselves the things that are being accomplished in a program which has been designed to reduce flood damage on the tributary watersheds of the Washita River. A second reason for our coming is to focus the attention of the nation on this program, for the people of the Washita River Watershed, aided by their government, have set out on a tremendous undertaking which, when completed, will be a good job done and a strong inducement to the people of other watersheds to take hold of the flood control work in earnest.

Today we are observing the unfolding of a new plan of attack on the forces which take the lives of human beings, destroy crops, damage or ruin agricultural land, and take heavy toll of rural and urban property. We are tackling this problem at the very beginning, on the small watersheds far upstream where the raindrops first begin their journey from the land to the sea. From time to time I have pointed out that floods are no more than raindrops, infinitely multiplied and allowed to concentrate into uncontrolled torrents, which sweep destructively over the banks of streams.

If, in a flood reduction program, we can force this water, or even a considerable part of it, to delay its race to the sea, we have won a part of our objective. Our aim, then, is to hold back as much as possible of the surplus water so as to reduce the height and destructiveness of floods.

We do not claim, in setting out on this undertaking, that we can control major floods with this kind of work alone. Some of the peak flow can be cut down, and this will help; but for the heavier floods there will be needed additional controls in the way of reservoirs, levees, and other main channel operations.

These major engineering operations are the responsibility of the Corps of Engineers. It is our belief that a combination of these programs -- the main channel program supplemented by the upstream program -- can get the job of preventing and controlling floods accomplished.

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1. Address by H. H. Bennett, Chief, U. S. Soil Conservation Service, Washita River Watershed Flood Control Dedication Celebration, near Cordell, Oklahoma. July 8, 1948.



At this point, I think it should be mentioned that the two programs have been planned by Congressional action, not as any process of substitution of one for the other, but rather for the one to supplement and aid the other. I happen to know when and how the Flood Control Bill was first changed to add on the upstream phase of the work -- and that change didn't take place altogether accidentally. I am referring to the occasion, about the middle 1930's, when it was suggested by the Secretary of Agriculture to the Secretary of War that efforts be made to permit the soil and water conservation efforts of the Department of Agriculture to become a supplemental part of the flood control program. There was considerable discussion of the matter, but the suggestion was finally accepted -- and here it is going into action right before us.

I want to add this point, that it has seemed to me the job of the Department of Agriculture follows closer along the line of flood prevention, while the major engineering operations of the Corps of Engineers follow more nearly along the line of control of floods -- after the water gets down into trunk stream channels. This makes a perfect fitting together of the two phases of a comprehensive, completely coordinated program of flood control.

#### Cloud Creek Detention Dam

This dam we have seen here today is symbolic of a comprehensive program of proper soil and water use and treatment already well under way. It is true that it is the first such structure, built entirely for flood control, to be completed in such a program. But the program of which it is a part has been going on for months. Other such dams are under construction even now and still others are under contract and are soon to be started.

#### Flood Control Surveys

Congress has authorized more than 600 watersheds for preliminary flood control examination and survey to determine whether the benefits to be derived from such a flood control program would justify the cost. The Department of Agriculture has completed preliminary examinations on 154 watersheds or portions of watersheds, and it has furnished 18 survey reports. Congress has authorized programs of watershed improvement on 11 watersheds in various parts of the country -- of which this is one. Some work has been done in each of these 11 watersheds.

#### Flood Control Activities of the Soil Conservation Service<sup>2</sup>

The survey work and the operations by the Soil Conservation Service are carried on through our seven regional offices under the general direction of my office in Washington. The Division of Water Conservation in Washington and, respectively, in these seven regions directs the preliminary examinations and surveys and the preparation of work plans.

Turning back a few decades to the time when the land was in virgin condition, there were overflows occasionally, but they were not so violent as now. The land had not been plowed for cultivation. The rains that fell soaked into the ground, nourishing the plants and replenishing the underground water. The streams, because their sources were undisturbed and there was little silt dislodged from the

2. Bennett, H. H. Soil Conservation. McGraw-Hill. 1939. Soil conservation and flood control. pp. 596-616. See also Outdoor America. April, 1947. p. 8.



hillsides, ran clear. Nature was in balance.

There are those in this audience who can remember the way the land here looked in those days. Some of you -- like John Cassady of Cheyenne -- can remember the settling of the Washita. There was much tall grass, roaming buffalo, and clear streams with open channels.

The forces that made these rolling, grass-covered hills and plains have not changed. The change that has taken place, to the everlasting detriment of the land, has been made by man himself, and man has been the loser.

The situation changed sharply during World War I. The nation needed cotton and wheat to fight a war. Prices of these and other farm commodities soared to high levels. That brought about the clearing off of a limited amount of timber and the plowing up of hundreds of thousands more acres of grassland in the Washita watershed. And the land yielded its bounty in response to the need.

But following 1917 we have seen the costly disadvantages of using the land without consideration of its character and adaptability. We have seen much of the precious topsoil of the Washita Valley washed away with each rain. We have seen stream channels so choked with the debris of erosion as to reduce their capacity to carry water, by hundreds of thousands of acre feet. We have seen the flood waters drown crops and scour the land of the watersheds. Some of you have even known the tragedy of the loss of relatives and friends as floods swept down the tributaries of the Washita.

Many of you have been concerned for a long time over this wasting away of the valley's soil resource while, at the same time, the problem of flood damage was on the increase. Recently it was called to my attention that one of the chambers of commerce in the Washita watershed made a study of erosion conditions in the area as early as 1930. Many of you realized at that time, I am sure, that this part of Oklahoma was losing something of great value to its economy and that this wastage -- of good land especially -- was playing a part in adding to the severity of the floods that were seriously hurting the whole watershed area.

It is appropriate, I think, to recall two events that influenced our efforts toward both soil conservation and flood control. On the night of April 4, 1934, a 10-inch rain brought death and destruction to the locality of Hammon. Twelve persons died that night in the waters that rushed down Kiowa, Sandstone, and White Shield Creeks and on down the Washita. On May 12, 1934, that same year, only 38 days later, there occurred the worst of all the famed "black blizzards" during what is commonly referred to as the "dust bowl" days.

The flood served to spur the residents of the Washita Valley to more determined effort to get a flood prevention program started. The duster, carrying millions of tons of soil from the unprotected fields of the Great Plains, sent its black clouds across the capital of the nation and far out over the Atlantic Ocean. These things and their numerous companion disasters elsewhere served at least one purpose: They help<sup>ed</sup> impress the people of the country, and its lawmakers, of the vast cost of needless land abuse.

In the years that followed, you people of Oklahoma were busy. You worked out a plan designed to halt the devastation on the Washita, and you called on your representatives in Washington for assistance. Your efforts, combined with similar efforts from other localities, resulted in the 1936 Omnibus Flood Control Act.



adopted by the 75th Congress. This act defined and unified the flood control activities of the Department of War and the Department of Agriculture. As already indicated, it made the Department of Agriculture responsible for flood control operations on the watersheds, on the upper reaches of the tributaries where the floods actually begin. It made the War Department, through its Corps of Engineers, responsible for the larger flood control structures on the main stems of our streams.

The Soil Conservation Service and the Forest Service were the Department of Agriculture agencies designated to carry out its flood control activities, the former working mainly in those areas where agriculture is importantly developed, and the Forest Service in the upper headwater areas, occupied to a large extent by national and state forests.

#### Washita Survey

The Flood Control Act also authorized the two Departments to conduct surveys of the Washita to find out whether flood control operations, both upstream and down, would produce benefits that would justify the spending of public funds.

The Department of Agriculture survey covered studies of various phases of the watershed problem: As the agricultural history; type of land, climate, especially rainfall; and the effects of changing conditions on the economy of the watershed. The survey report showed, among other things, that:

- Some 900,000 acre feet of soil had been lost between about 1918, when the growing of clean-tilled crops showed a marked increase, and 1938;
- Approximately 1,100,000 acres had suffered severe erosion;
- Around 2,000,000 acres had suffered some erosion -- from slight to moderate;
- About \$2,250,000 annual flood damage, with farmers bearing about 96 percent of the loss;
- Approximately 2,700,000 acres in cultivation;
- Some 250,000 acres, formerly cultivated, abandoned; and
- About 207,000 acres in need of permanent revegetation.

These results reflect erosion conditions in the 1928-'39 period. In many parts of the Washita watershed the conditions later became much more severe than the earlier figures reflect. Some of the land that was classified as suitable for cultivation, with protective measures, in 1938 has now been so damaged it is impracticable to cultivate it further. Such areas have also become sources of quicker runoff and increased production of sediment.

The survey party took into account, as well as possible, the estimated benefits that would result from the spending of public money to correct these conditions, and these were most encouraging. The estimates, based on 1938 price levels, were as follows:

- Benefits to farmers and ranchers, approximately \$5,000,000 annually; and
- Reduction in flood damage, \$357,000 annually.

For each dollar invested, the estimated overall benefits were put at \$3.85.

By 1948 prices and costs, the damage to land and crops would be doubled or more. Benefits likewise would be increased greatly in dollar value. By any measurement, flood damages are costly and should be reduced as much and as rapidly as may be practicable.



## Washita Valley Improvement Association

About the time the flood control report was being prepared, the citizens of the Washita Valley gathered at Chickasha and formed the Washita Valley Improvement Association. This organization announced that its purpose was to promote the improvement of the Washita Valley through flood control, soil conservation, and proper use of land and water. The objectives of this organization and its efforts to carry out these objectives are a tribute to the vision and the courage of the people of the Washita Valley.

### Soil Conservation Districts

Probably most of you here know how soil conservation districts are organized, how quickly they have spread over the country, and how cooperatively and effectively the farmers in districts are going about their work. For the information of the others and to re-emphasize again the responsibilities of the men who manage the affairs of these districts, I want to say that the districts, in my opinion, represent the foundation stones on which the soil conservation program rests. These districts in most states are units of state government. The men who serve on the district boards here in Oklahoma are landowners who are chosen by ballot. The basis of this program is as democratic as it has been possible to make it, and that is the way it should be.

In setting out on this nation-wide districts program, the people of Oklahoma helped lead the way. Your legislature was quick to act in adopting the state soil conservation district law and quick to start the first district in the Southwest in operation. That, I think, is typical of the way you people do things down here. You move in a straight line, and fast.

When the standard district law was submitted to the states in 1937, I would have been gratified indeed if 10 states had adopted it within 10 years. But all the states adopted it within less than 10 years. Now our territories have adopted soil conservation district acts, and a number of foreign nations, too.

These districts, including those in your own Washita Valley Council of Soil Conservation Districts, cover more than a billion acres. They include almost two-thirds of the farmland and about three-fourths of the country's farms and ranches. Oklahoma is near the top of the list in district organization, with 93 percent of the state within the boundaries of 77 districts by May 1 this year. They include more than 33 million acres of Oklahoma's approximately 36 million acres of land in farms. Many of you here today are soil conservation district supervisors and know the solid foundation on which your districts have been built. You don't need for me to remind you of the liberal contributions of time and effort which enter into successful soil conservation district organization and direction, reflected in such concrete accomplishments as the Washita flood control program which brings us together here today.

Such accomplishments, on the farms in the Washita Valley, throughout Oklahoma, the Southwest, and the United States, speak for the success of this unique soil conservation district organization. It is too soon for the July 1 figures to be in, but I can tell you that during 1947, for example, farmers in soil conservation districts applied, with Soil Conservation Service assistance, an average of around 25 percent more conservation practices to their lands than during the preceding year. This progressive accomplishment was realized in spite of the fact that the Service had less technical help for districts and had to spread it among many more new districts. That explains why there were about 45,000 more applications filed



by district farmers in 1947 for conservation for conservation surveys, planning, and treatment than new plans could be prepared, bringing the backlog on file to around 200,000 formal farmer requests for conservation plans. Of course, thousands of those have been serviced in the past six months, but added thousands of new applications have been made.

Up to January 1, this year, farmers and our technicians, working out in the fields together, had prepared throughout the nation more than half a million completely coordinated conservation plans of whole farms and ranches in soil conservation districts. These plans cover more than 160 million acres, and the acreage on which conservation treatment had been applied totaled more than 76 million acres in districts alone. In order to get a comprehensive idea of how we are progressing with the basic soil and water conservation job, we need to add the additional millions of acres planned and treated under other programs in which our Service has participated, plus the large acreage taken care of the first half of this year. In addition, nearly 270 million acres of detailed conservation surveys had been completed by the first of the year -- surveys which are necessary as a foundation for sound farm planning and treatment, just as flood control surveys must precede actual operations.

The gratifying rate at which Oklahoma farmers and ranchers are moving ahead with their soil conservation work likewise is shown by the figures on accomplishments to January 1, this year. They showed about 34,500 active plans in the districts alone, with 7 3/4 million acres planned and nearly 4 million acres treated. I noted such items as these going to make up that healthy total of application of conservation measures on the land: 1 1/4 million acres of contour planting and a million acres of cover crops; close to 2 million acres of stubble-mulching and 45,000 miles of terraces and diversions; more than 3 1/2 million acres of conservation range stocking and 15,500 farm and ranch ponds; more than half a million acres of range and pasture seeding, and numerous other measures applied.

Together, in the right combinations suited to the capabilities of the land, these measures provide the only complete and lasting conservation of our productive land. I refer to the treatment of each acre according to its needs, and the use of every acre for the purpose to which it is properly suited. There is no substitute for this acre-by-acre soil and water conservation planning and treatment, no practical or economical shortcut -- no other way to do the job properly, scientifically, and most effectively.

And it is only by this means, in the long run, that we can be sure of permanently safeguarding the good land we have left before it is too late. If we had embarked on such a common-sense and foresighted program 50 or 100 years before we woke up to what was happening to our land, we wouldn't be faced with the situation we are today -- of still shrinking productive land acreage at a time when our own and the world's population is increasing rapidly, with the end not yet in sight with respect to heavy drains on our land to meet world-wide food and other demands.

We have left, for example, only about 460 million acres of high grade cropland in the United States, as well as can be determined. But all but about 100 million acres of it is subject to erosion or other forms of depreciation, when used without safeguards. And from 80 to 100 million acres of it needs clearing, irrigation, drainage, or other improvements to make it productive.

Around a fourth of the cropland is being damaged at a critically rapid rate by erosion. Much of this approximately 115 million acres will be permanently damaged and some of it ruined for further cultivation every year it is cropped without



protection. It ought to be protected -- and can be -- with treatment like that which so many of you are carrying out in the Washita Valley, during the next 10 to 15 years, or not later than by about 1960. Still another area of cropland of about the same extent should, for the same reason, receive adequate protection by not later than about 1970. Additional millions of acres on which erosion is beginning or is likely to begin at any time must not be neglected, nor must we overlook the millions of acres of range land also affected.

You know, without my reciting figures for you, how your own Oklahoma lands have suffered, some of them in only half a century of agricultural use. I am convinced from what I have seen and from what I know in general about your soil conservation progress out here that you are alert to the urgency of the situation. The job still ahead is such a big one, however, that you cannot afford to relax for a single season or for a single day in pushing ahead to its completion.

### Retardation of Runoff

At the outset I pointed out that our purpose today is to recognize an important milestone in our campaign against floods and erosion damage. I would like to emphasize the importance of this occasion. In this new treatment of agricultural land to assist in the control of surplus rainfall, we have started a new program. For the first time in history, we are going into the small watersheds, far upstream and out on tributaries of our main waterways, and there we are seeking to provide relief from floods to the small farmer or landowner who year after year has been undergoing hardships through crop and soil losses. Frequently, the accompanying flood damage along these upper "Little Waters" accounts for 75 percent of the total watershed flood damage. That gives you an idea of their importance. We have developed in this program a unique combination of soil conservation, engineering, and forestry practices designed to safely dispose of surplus water and also to make the best practical use of the water that otherwise would be wasted.

Our main objective is to retard the discharge of water from upstream areas until it can be absorbed by the land or carried off without destructive effects. And while we are thus retarding runoff, we are at the same time, and by the same means, reducing the effects of erosion; and we are storing in the soil for later use the water that may mean a good crop instead of a poor one or a failure. Also, we are, by the same operation, reducing the rate of sedimentation of stream channels, ditch reservoirs, and productive bottomlands.

In our normal conservation work the objective has been to keep our agricultural land permanently productive while in use. In our flood control operations more emphasis is put on the task of slowing down runoff. For both purposes, we terrace sloping land, plow it on the contour, strip crop it, fill gullies, take steep, highly erodible land out of cultivation and put it under the protection of trees or grass, and so on. Protection of waterways with grass, protection of land with stubble-mulch farming, and building up the fertility of the soil also aid both flood control and soil conservation operations. In doing these things we are prescribing for our agricultural land the treatment that it needs to make it permanently and continually productive. We do this in much the same way that a doctor diagnoses the needs of a patient and seeks to restore him to the peak of health.

In watershed flood control work we go considerably beyond the normal requirements of soil and water conservation. Our aim is to hold back for a longer time the water that falls on cropland or rangeland. So, in this program we give special attention to measures, including engineering, that help to hold back water and slow down its flow.



Let us suppose that 50 to 80 percent of the landowners of a small watershed (such as this one) have treated their land with a coordinated soil conservation program. They have terraced their farmlands and are tilling their fields on the contour. They have adopted soil-protecting and soil-improving rotations, and they are using all the other measures that their land needs for the maintenance of its productivity permanently. There still, however, would be damaging runoff and sediment loss (water-transported erosion material) from the area. The sediment mostly comes from the areas of unprotected land, treatment of some of which lies beyond the means of individuals or even groups of land owners. To retard this runoff and hold back the sediment may require special measures which may offer little benefit to the farmer on whose land they are built, but which are of great value to other farmers and residents downstream. Such measures are not often planned or applied in soil conservation districts outside of flood control project areas.

For example, we are now standing near the site of a small detention reservoir, designed by the flood-control technicians of the Soil Conservation Service working in cooperation with the local soil conservation district. There will be many such reservoirs in the Washita project. Each is designed to impound water temporarily and release it at a rate which will not exceed the capacity of the channel below.

This reservoir is designed to provide enough storage capacity for the runoff from the heaviest rain that may fall over a 25-year period, or 900,000 gallons a minute. This reservoir was constructed to reduce this rate of discharge to 25,000 gallons a minute. This slower rate of runoff will continue for days instead of the whole reduction taking place in a few hours.

All the ordinary soil and water conservation measures, applied over this entire sub-watershed of 5,900 acres, probably would not accomplish this end in themselves. There would still be a need for a structure of this kind to keep runoff after a heavy rain low enough for the stream system to handle it without damage.

#### Other Flood Control Tools of the Soil Conservationist

In addition to the reservoirs, there are provisions for structures for waterway stabilization and gully control. Both contribute toward runoff retardation also. These include earth gully-plugs, drop-inlets, drop structures, and flumes. Such structures are designed not only to stabilize the grade of the waterway or gully, but to hold back sediment while the erosion above is being controlled through the establishment of vegetative protection. Many of these structures may not be needed for ordinary soil conservation purposes.

Floodwater diversions are built to divert hill land runoff and thereby prevent floodwater and sedimentation damage to highly productive bottomland. Flood control waterways are used to carry hill land runoff safely through cultivated areas, thereby preventing floodwater and sediment damage to productive cropland. They may serve as outlets for floodwater diversions or other flood control structures.

In some places it may be necessary to straighten, clear, or enlarge the stream channel in order to reduce the frequency of flooding of adjacent cultivated land.

Cooperative roadside erosion control also contributes to the stabilization of roadside ditches, especially through proper shaping and by establishment of vegetative protection. This is an effective means of reducing the rate of sediment production. It also materially reduces the cost of road maintenance.



Revegetation of critical floodwater and sediment source areas, such, for example, as critical slopes in fields, is another important tool in this program. There are many areas of land which have been so severely eroded that their usefulness for cultivation has been ruined. Where these areas are larger than a few acres, or are very numerous, it may be beyond the means of an individual farmer or a group of landowners to stabilize them. The revegetation of these areas, and the control of sediment produced by them while this is being accomplished, will be a public benefit in reducing sediment damage to lower-lying land, stream channels, ditches, and reservoirs.

Ordinary soil and water conservation measures are for the protection and improvement of the land on which they are applied, and consequently the principal benefit is received by the operator or owner of the farm on which such work is done. Therefore, it is only proper that the farmer should bear the principal cost.

On the other hand, the special measures and structures used in aid of flood control are designed to benefit bottomlands along the major tributaries and their branches and to keep sediment out of stream channels and reservoirs. Because these are public benefits, the public should bear the major part of the costs, so long as they are justified by the benefits to be expected.

This program of watershed improvement is good business, and I like to think of it in that way. When any of us invest our money in an enterprise, we want it to be a safe investment, and we want it to yield a reasonable rate of return. This program is good business for the farmers and the ranchers, and it is good business for the merchants and the professional men -- everybody -- in the communities involved. The measures used in this program fit in well with soil conservation measures. Together these programs protect land, crops, livestock, and buildings. They aid in holding and building up soil fertility, often increase production, and make farming operations easier.

### Benefits

I have mentioned the benefits that are considered when a flood control program is planned. I will give some examples which have been passed on to me from some of our field technicians.

Below the two detention reservoirs on this Cloud Creek watershed are 179 acres of bottomland which will be protected directly by these dams. Protection of this land from flooding will mean that 11 acres now idle will be turned into irrigated cropland, 7 acres of pasture will become cropland (4 acres of it to be irrigated); 141 acres will remain in cropland and its productivity will be greatly increased; 5 acres will remain in pasture and 15 acres of brush land can be cleared for pasture as needed. Conservatively we estimate that the production from this 179 acres will be increased from 35 to 40 percent as a result of the installation of these measures.

In this particular watershed, in addition to the two detention dams, there will be six drop-inlets, nine earth gully plugs, 3.7 miles of flood control diversions, one-half mile of roadside waterways and four sod flumes. You have observed that this work is nearly finished in this watershed.



When the combined flood control and soil conservation programs have been applied to the land in the watershed -- more than 4,000 acres -- I am confident that you will find the value of the land has been doubled, some of it trebled.

One of the farmers here, E. E. Weaver, tells our field men that he has tried alfalfa in one of these bottomland fields year after year. Invariably it has flooded out. The man who farmed the place before him tells the same story. But now Mr. Weaver can grow alfalfa on his bottomland and it will not be destroyed by floodwaters.

Another farmer, Dave Merkey, estimates that this program will increase the value of his farm by from \$3,000 to \$4,000. Wheat on his bottomland produces 30 to 50 bushels an acre when it does not flood out. When the land overflows, he gets nothing.

There will be benefits from this work on below here, on South Cavalry Creek and on Main Cavalry Creek. I am told that there are 170 acres of bottomland on South Cavalry and 482 acres on Main Cavalry which this work will help protect. We call these secondary benefits.

Getting such a program as this on the land is only a part of the problem. Keeping it there, to yield benefits year after year, is likely to be more of a problem than getting the various practices installed. There is where the soil conservation district can perform one of its greatest services. And that is why it is as equally important to make a conservation farmer or a conservation rancher as it is to build a conservation farm or ranch. These flood control and soil-security investments must be protected. Such protection must come from the men and women who own and operate the farm and ranch lands. These individuals understand that land has strength and weakness in varying degree and that it must be used only according to its capacity to produce in lasting safety.

(Continued)



### Soil Conservation Pays

Fortunately, we know that soil conservation farming and ranching yields immediate benefits. We know that farm yields can be expected to go up a certain percent on the average, and that ranching benefits also will increase.

A study of soil conservation effects on 275 farms in the Upper Washita Soil Conservation District showed that, when the program of application was from 70 to 100 percent complete, the following per-acre increases in yields were reported: Grain sorghum 34 percent, corn 29 percent, cotton 21 percent, and forage from grassland 18 percent. Cultivated land was reduced 5 percent, and grazing land was increased by 6 percent.

In the Cross Timbers portion of the Washita watershed, the operation of 191 farmers on 38,827 acres of land was studied in the same way. The program of soil conservation on these farms meant 24 percent more cotton, 22 percent more grain sorghum, 40 percent more corn, and 39 percent more forage in the pastures. Cropland was reduced by 14 percent; grazing land was increased by 30 percent. A total of 1,400 acres of idle land was put back to work.

So you can see that soil conservation is paying its way. Every farmer or rancher is a business man. And as business men every one of them is ready and eager to realize more return from his work and his investment. The fact that in applying a program of soil conservation he is putting his agricultural plant on a sounder, more secure basis is a still further inducement to the owner and operator. It would be small man indeed who would not find satisfaction in knowing that he was caring for his land in the way it ought to be cared for, and in knowing that, in addition, he was making possible the permanent use of his acres for generations to come.

### Productive Land and Hunger

Let's look for a moment beyond the limits of the Washita watershed and consider how this program affects others. It is my feeling -- as I frequently repeat -- that everybody is or ought to be concerned with the permanency of our productive land, because it is the source of our food, most of our clothing, all of our wood supplies, and of an increasing number of the raw products of industry. It is my conviction that of all the problems confronting the world today the toughest of them is how to feed a rapidly increasing population from a limited and diminishing supply of productive soil. Over a vast area of the earth's surface the population has surpassed or caught up with the food-producing possibilities of the land, or the number of people is moving rapidly in that direction. There are millions of people alive today who have never known and never will know what it is to have enough to eat. Year by year the number of hungry millions, because of present methods of food distribution and improper use and protection of the land, is likely to continue on the increase.

The stark truth is that we are running out of productive land. We are wasting it rapidly and unnecessarily. It is a grave indictment against our thoughtlessness in America that we have been using up, or destroying, what we had with such recklessness.

Hungry people are discontented people, quarrelsome, un-neighborly. Hunger breeds lawlessness and strife wherever you find it. Hungry people cannot be happy, peaceful people, and the world is not likely to achieve permanent peace until its people can be properly fed.



That is my reason for saying that a long-range program of soil and water conservation is one of the greatest needs of our world. Never before in man's history has an acre of good land been so important as it is today. We have in the world today four billion acres of land that can be cultivated. It is not all good land. Some of it is of medium quality, or poor. But it must produce the food that 2-1/4 billion people need to sustain life. The number of people on earth is growing at the rate of about 20 millions annually. So the per capita acreage is growing smaller and smaller -- while our population grows and our soil washes away.

Even here in the United States we are permitting the loss of our land at the rate of 500,000 acres a year, according to our measurements and estimates. This is in spite of the highly successful efforts that we already are putting forth to halt this waste. So you see how urgent and basic is this soil conservation task we face.

### Research

Since 1929, the Department of Agriculture, in cooperation with the state experiment stations, has been conducting research in soil and water conservation as an aid to our action program on the land. Since 1934 the Soil Conservation Service has been helping farmers and ranchers to apply soil and water conservation practices to the land. This work is being done now through the 2,000 soil conservation districts already organized, and it is accomplished by the farmers and ranchers themselves, along with the assistance given by technicians of the Soil Conservation Service working in the districts. During the fiscal year of 1947, the farmers and ranchers of this nation applied soil conservation practices to 20 million acres of land. This treatment included the use of all needed changes in land that we know about.

We have been making encouraging progress, but we still have far to go. About 85 percent of the land in the United States that still needs acre-by-acre conservation treatment -- that is treatment according to the kind and capability of the land -- is yet to be treated. That is a big job. It is a challenge to the men and women of the nation.

In getting this huge job done, we have on our side some very effective weapons. We have a constantly growing understanding of the problem on the part of individuals and organizations in all segments of society -- educational and religious, agricultural, commercial, and professional. We have the organization of soil conservation districts, set up by law to accomplish this specific task, and these districts are led by aggressive, intelligent local leaders who are going ahead with the job. We know how to do the job, and where the job is, and what it takes to get it done. We have scientific, practical, and economical techniques that come from 20 years of study and experience on the land. We have effective programs for every part of the nation and for nearly every type of land. And, finally, we have in the Soil Conservation Service the first and by far the largest corps of trained, expert soil conservation technicians in the world.

Aligned against us are the forces of injured nature that have a long start on us, because of our heedlessness over the years. I am confident that we will win in this fight, just as we win in every fight in which our people are aroused. In this effort watershed treatment in aid of flood control has a big part. The structures that we are using in this program have been designed with engineering precision to do special jobs in holding back a part of the surplus water for a time. They are built at public cost, because the public shares in their benefits. They are devised to help protect life, agriculture, and property from damage, and investigation in the case



of each structure has made certain that benefits will justify the cost. This is no hit-or-miss program. It has been carefully studied, carefully planned, and it is being executed with the same care and skill. We know that this program will accomplish what it is designed to do.

I think it is entirely fitting that we gather here today to recognize the contribution that this type of agricultural operation will make toward the continued prosperity and the security of the Washita Valley. This floodwater detention dam, and these other structures designed for flood damage reduction are monuments to the vision and the faith of the men and women who live in this valley. You have fought long for this program. You have studied the means for its accomplishment, and you have worked hard for the things you are seeing here today. It is my earnest wish that this program here will be duplicated in many watersheds over the United States, so that the people of the nation may enjoy the benefits of this new program which you of the Washita Valley in Oklahoma have so ably helped to inaugurate.

With your leave, I am going to join you in your rightful enjoyment of these prospective and deserved benefits. They are good for my soul, too; for this way lies security, good will among people, peace.







FLOODS

James

# Where Floods Begin

Complete Watershed Treatment on Sandstone Creek  
In Washita River Valley of Oklahoma and Texas  
Shows How to Reduce Damage and Maintain Soil



This picture shows the eroded and unproductive soil in a part of the Sandstone Creek watershed before soil conservation and flood prevention measures were applied to the land to control runoff and maintain productivity.

Another part of the same watershed--similar soil, similar slopes, similar rainfall--now producing good crops because complete soil and water conservation, including flood prevention measures, make the land secure for continued production.



U. S. DEPARTMENT OF AGRICULTURE  
Western Gulf Region, Fort Worth, Texas

SOIL CONSERVATION SERVICE  
February, 1952



# Where Floods Begin

A flood is little more than a headline in a daily newspaper to many people. But to those in the affected areas, a flood means washed-out crops, damaged homes, eroded lands, and often loss of life's savings.

For example, the 8,100-square mile Washita River watershed in Oklahoma and Texas suffers an average annual flood damage of \$5,700,000. About 70 percent of that is direct damage to crops and pastures.

Then consider just one small tributary of the Washita, Sandstone Creek in the rolling red plains of western Oklahoma. Here we find beef producers, dairymen, wheat and cotton farmers. Taken alone, Sandstone Creek seems insignificant to the casual observer. Its watershed is only 15 miles long and 6 miles wide, an area of 65,000 acres.

Yet this little watershed has averaged nine floods a year, with annual damage of about \$60,000. Soil erosion has so severely damaged portions of the watershed that they no longer are suitable for crop production. In fact, about 72 percent of all the flood damage in the Washita occurs along the small tributaries.

Sandstone Creek and other major tributaries to the Washita flood more frequently than the main river. That's because tributary floods are caused by short, intense storms which cover a relatively small area. Such storms occur far oftener than the long-duration storms over large areas which are necessary to produce a main stem flood. Fig. 1 shows that more than 90 percent of the flood damages on typical Washita tributaries is caused by small floods of the size that occur more frequently than once in 10 years.

It amounts to this: Creeks flood more land than rivers do, and they flood more frequently.

That's why the U. S. Soil Conservation Service is tackling the problem of flood-damage reduction in tributary watersheds above the heads of small valleys. It does this in cooperation with soil conservation districts and cooperating farmers and ranchers.

The nearly completed program on Sandstone is twofold. It includes not only land treatment measures but also small retarding structures built upstream. Neither alone is capable of providing adequate flood damage reduction.

Land treatment measures and land use changes are aimed at reducing runoff and erosion. They include cover cropping, strip cropping, seeding of grassland, terraces, field diversions, and similar measures.

Completion of the land treatment program in the Sandstone Creek watershed, it is estimated, will reduce annual floodwater and sediment damages by about 30 percent.

That's not enough. Small upstream dams and related structures also are needed to minimize flood damage. The plan of these measures is shown in Fig. 2. A system of 24 floodwater retarding structures--small upstream dams costing an average of about \$35,000--is nearing completion at a total cost of about \$850,000.

A typical upstream retarding structure has an average drainage area of 5 or 6 square miles. The detention pool is designed to hold back at least the maximum runoff to be expected once in 25 years.

The spillways are designed for the flood of 100-year frequency occurring when the detention pool is filled. Flood storage capacities range from 78 to 3,850 acre feet.

Floodwater will be released slowly through automatic draw-down tubes. As a result, the water will be carried away without overflowing the bottomlands below. Water held back by these structures, generally located at the extreme head of flood plain areas, covers less than 5 percent of the bottomland. The area flooded behind any one dam is so small that it does not constitute a serious loss to the farm or community in which it is located.

In addition, 17 drop inlet structures are being constructed for grade stabilization and sediment control at a total cost of about \$85,000.

What are the benefits?

It is estimated that future flooding will not exceed an average of 110 acres annually, out of the total flood plain of 4,700 acres, causing an estimated average annual damage of only \$1,236. The estimated 90 percent reduction in annual flood damages in the little watershed will average \$57,461.

Benefits do not end there. The system of upstream detention structures allows a more intensive use of flood plain lands. Farmers say that land now producing low returns from small grain or pastures, because flooding had been so frequent, will now be converted to high-value alfalfa. Estimated annual net benefit from more intensive land use will be more than \$11,000.

But the biggest benefit of all will be the protection of irreplaceable topsoil, our most valuable basic resource.

The measures installed on Sandstone Creek will produce approximately \$3 of benefit for each dollar of cost.

Farmers and ranchers in the Sandstone Creek watershed have cooperated wholeheartedly with the program. Soil and water conservation plans have been prepared on 58,900 acres, or 90 percent of the watershed, through cooperative agreements between farmers and ranchers and the locally

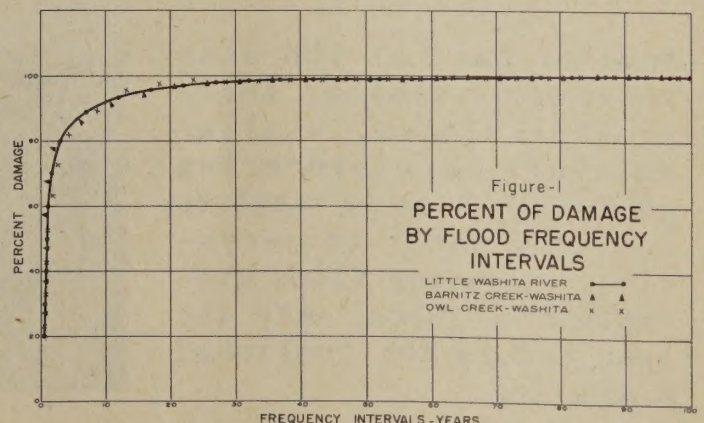


Figure 1. This graph is the engineer's way of showing the percentage of total damage that results from floods of various frequencies. Note where curve crosses first line from left (10-year frequency). It indicates that more than 90 percent of total damage is done by the kind of floods which occur often--at 10-year intervals or less.



Easements for the necessary detention structures have been granted by the landowners without charge to the soil conservation district. Waterflow retardation structures will be maintained by group organizations of benefited farmers under agreements with the Upper Washita and the North Fork of Red River Soil Conservation Districts which have assumed the responsibility for maintenance. The land treatment measures will be maintained by landowners or operators of the farms on which the measures are installed. Governing bodies of the districts make periodic maintenance inspections with technical guidance from the Soil Conservation Service.

The installation cost of the structural and land treatment measures will be about \$74,000,000, of which state and local interests are expected to

An adequate program of soil conservation and flood damage reduction measures means increased production for today's farmer and rancher, less flood damage, a minimum of erosion, security for the farm family, and protection of our nation's agricultural land for the requirements of future generations.

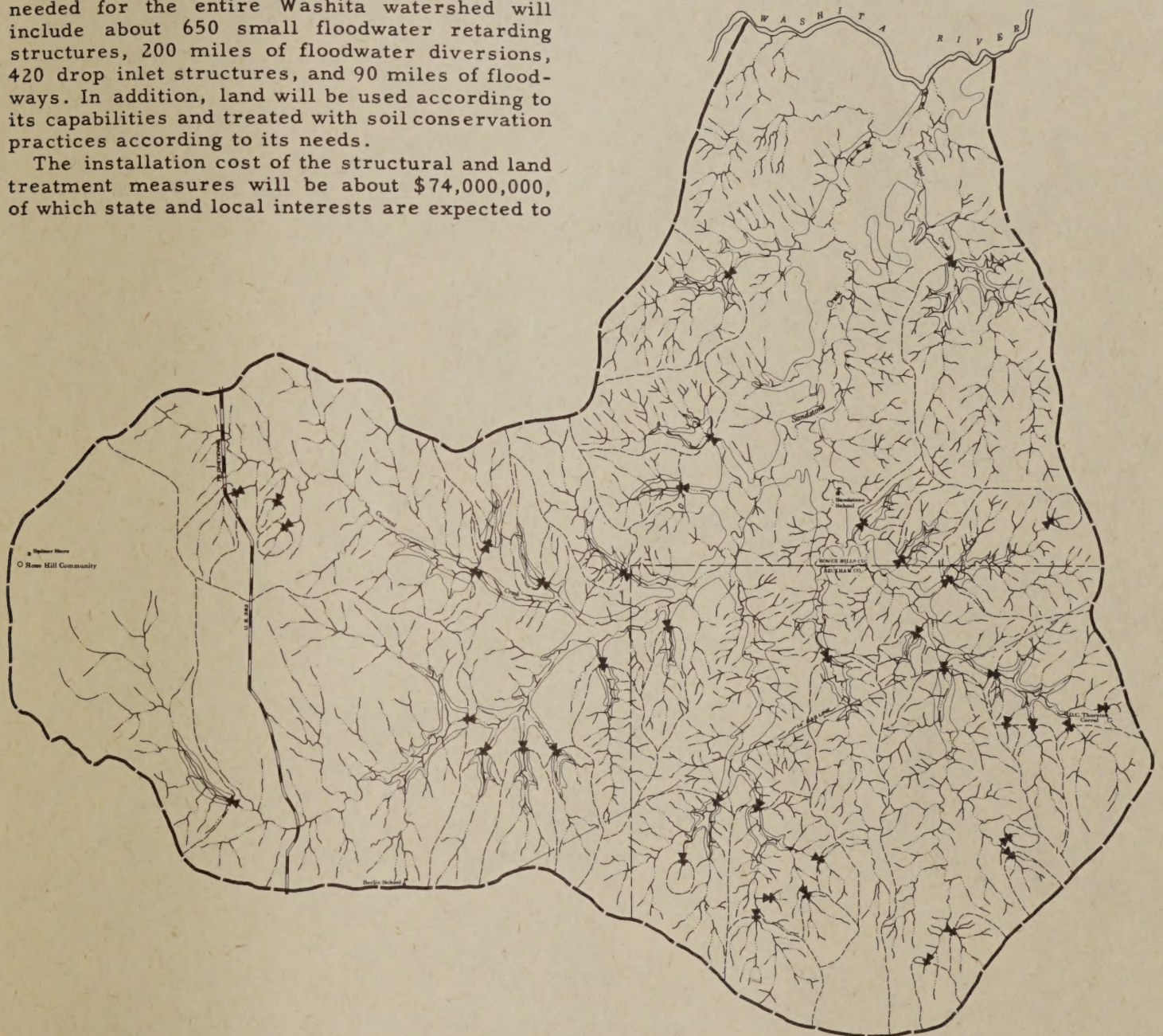


Figure 2. This is a map of the Sandstone Creek watershed. The land drains generally north and east to the Washita River at upper edge. Symbols show the location of the small upstream dams. These, with other land treatment, will prevent most of the damage that would result from the largest single runoff expected once in 25 years.







For several generations Congress has been voting "Pork Barrel" appropriations to further its own political ends through providing funds for useless government projects and sinecures (jobs with pay but without work) for favored individuals.

Among the chief participants in this governmental boondoggling have been the U.S. Engineers, who, through money set aside for rivers and harbors, have for over 50 years been building dams and dykes for the avowed purpose of establishing 9 foot channels in all the Nation's principal rivers; also millions of tax dollars have been wasted on locks and dams allegedly to promote and facilitate navigation.

From the very outset it could be seen that dams and dykes were a hindrance, rather than an aid, and served only to cause a shallowing rather than a deepening of river channels. However, despite the demonstrated detrimental effect of dykes and channel-diverting dams, and despite public criticism and derision, the construction of these worse-than-useless projects continues.

As for locks and dams: These too proved an utter failure. Instead of providing a navigable channel, actually the immediate effect was to put a "hump" in the river beds, in some instances raising the bottom of the stream to a point higher than the top of the dam. In addition they created a constant menace to human lives, each dam taking a toll of drowned victims.

There is yet another phase as to the harmful effect of locks and dams: Specific examples may be found at Saverton, Mo., Quincy, Ill., and La Grange, Mo., <sup>See notes on op. side</sup> as at each of these points the government has built locks and dams. Along the Mississippi, from Saverton upwards to 50 miles and beyond, wherever sufficient bottom land were available to justify construction of levees, such embankments will be found - many of them government built.

Back of these levees was found considerable low-lying land containing sump holes and like, being too wet for farming. This condition was remedied by the industrious, enterprising farmers by providing drainage facilities such as ditches and the setting of many miles of tile. Once almost worthless land was thus made highly productive for crops and the value enhanced from a few dollars per acre to upwards of \$250.00.

Then came the U. S. Engineers, and with their usual manifestation







of "The public be d-----" ethics, proceeded to build locks and dams at each of the three points above designated. In consequence of being impounded by the dams, the surface of the water has been raised to a level with the base of the levees and sometimes even over the berm. As a result of seepage, all of the low-lying land is now under water and suitable only for duck hunting. In addition, because of sub-irrigation, even high ground produces but a rank growth of plants with but little yield of grain. Bravo! Great are the U. S. Engineers!

These solipsistic, omniscient engineering geniuses have long speculated on damming up all the nation's principal streams wherever a dam site were afforded. They envisioned a scheme which, in point of magnitude would dwarf any, and all other forms of graft they had ever conceived. They had, however, remained in doubt as to the best means of deceiving the public until the general high water of 1937 gave them their cue: "Flood Control" was the open sesame that would raise the lid on the pork barrel. This was the gravamen that induced a calling of a convocation of all the nation's engineering intelligentsia. All of the "Kernels" and such arrived on schedule, and a plan of action was mapped out. They decided upon, and wrote a propaganda song, and then, after the music was composed, like the birds in the pie, all the "Kernels" began to sing. All the other members of the cult dutifully sang placebo, and the kept press (for a consideration, of course! ) pulled the diapason on the propanganda organ and the campaign was on.

1. One verse was devoted to the blessings of "flood control"
2. One sang the praises of the cheap kilowatt.
3. Another lauded the inestimable benefits of rural electrification.
4. Yet another extolled the exquisite beauties of power-dam lakes.

Now let us examine and ponder the subjects of the aforesaid verse. As to the subject of flood control, the theory is so senseless, and the case against it so plain as to render discussion needless. Nowhere have floods ever been controlled by any means whatever, nor will they ever be. They can no more be controlled than can the tides of the ocean, and for the same reason - there's just too d-----d much water!

2. Next the Engineer's representation as to the low cost of hydro-electric power has deceived no one that has taken the trouble to ascertain the cost of hydro-electric as compared to steam-electric power. Not only is steam-electric power incomparably cheaper, but further there is no limitation as to the extent of the latter, whereas hydro-electric

deemite 2 on p. side







into believing that a half dozen dam reservoirs would contain all possible flood water in the upper ~~White~~ water shed, but common sense, based on <sup>5</sup>observation and empiricism teaches us that if no more rain were to fall than would be required to fill the half dozen basins in question, that there would be no flood anyway - neither with nor without dams. Viewed from another angle: If the six basins of the proposed dams were completely filled, and then the water released gradually, say over a four-day period, the result would be no more than a moderate rise in the stream.

Many Batesville citizens are genuinely alarmed at the prospect of the Wolf Bayou dam. They justifiably think that the structure would provide a constant towering menace to their families and themselves. The test holes drilled at both the site of the Bull Shoals dam, as well as the site of the Wolf Bayou project, gave evidence of decided faults in the rock strata, besides disclosing many crevices, caves, and caverns, besides numerous underground streams. Because of these facts there can be no positive assurance that secure solid rock foundations are available on which to build dam structures. <sup>See note 3 on opp. side</sup> It must be conceded that this dam might break for any one of various reasons, such as, faulty design, defective material and workmanship, and bombing in the event of war. Nor can the possibility of an earthquake be ruled out, as history shows that in 1812-13 the land in northeast Arkansas rolled and billowed like water waves. On February 6, 1950, earth tremors were recorded at Lebanon, Mo., about 100 miles north of Bull Shoals. In the Spring of 1952 an earthquake of considerable intensity was recorded at Fayetteville, Ark. Since this dam, along with the exception of irrigation dam <sup>4</sup>projects, has no rational ground for existence, every effort should be made to block further engineering trespassing upon ingherent Public Rights.

I have often been asked the question, "What would happen to Batesville if the Wolf Bayou dam were built and were to break?" To this question I can, I think, give a fairly reliable answer. When the dam at Johnstown, Pa., broke, a 20 foot wall fo water was released traveling at 20 miles per hour, and in but a short period 5,000 persons were either drowned or burned alive. The dimensions of the Johnstown dam were 100 by 700 feet, as compared to 181 by 4,790 feet of the Wolf Bayou project. Reasoning from analogy, I should estimate that because of its greater dimensions, a break in the larger dam would precipitate an avalanche of



3. Rock and dam number 2, which is four miles below the site of the proposed Wolf Bayou project, had to be set on piling because of the absence of solid rock, and as may have been expected, it collapsed in the center and had to be re-built.



of water 30 feet high with a velocity of 25 miles per hour. Since Batesville is only about 14 miles distant, I would say that within 20 minutes the town would be washed away, and its citizens, for the most part, would all be down in "Davy Jones' locker."

Since the inauguration of the present "flood control" scheme many eulogies have been written as to the "improved technique" and "marvels" of modern engineering. Having personally seen a good illustration of "modern methods", only three years ago, I feel impelled to relate the particulars, as follows: In dredging over a shoal on White river,  $3\frac{1}{2}$  miles above Batesville, a government dredge boat piled up a ridge of sand and gravel. The U.S. Engineer in charge was so impressed with the beauty of this elongated mound that he decided to make it permanent by covering with concrete, and in due course the work was completed. It was to be another of those "multi-purpose" affairs, to wit: (1) it would serve as an everlasting monument to engineering skill; (2) it would divert the current in the desired direction; (3) it would serve as a guide to navigation; (4) it would provide a place for the birds to roost; (5) it would obviate the need of importing guano from South America. Why ship bird-dung from abroad with a local supply available?

Stupendous results were anticipated, but alas! like hundreds of other government-built dams and dykes, this "Eighth Wonder of the World" disappeared with the first flood. Illustrative of the farcical and fraudulent nature of dams it is relevant to note the U.S. Soil Conservation Service reports that <sup>2,000</sup>1200 so-called "flood control", "multi-purpose", navigation and "power dam" reservoirs are now completely "silted in" (filled up with mud). A nearby illustration may be seen at Forsythe, Mo., (Lake Tanycomo). Here 30 years ago, when the dam was first completed, the depth of water immediately above the dam was about 200 feet, <sup>See note 4 on op. side</sup> as compared to the present depth of only 15 (fifteen) feet. Engineers had speculated on dredging out some of the impounded mud, but an investigation disclosed a dangerous break in the dam structure itself, hence the plan of dredging was abandoned as both dangerous and futile. Then said the Engineers, with characteristic indifference: "Let 'er rip!"

Paul W. Glines  
General Delivery  
Batesville, Arkansas



4. I am not sure that the height of this dam is 200 ft. I have personally  
seen the structure but have no authoritative figure at hand.

W. H. Gilman  
General Delivery  
New York, N. Y.